SPECIFICATIONS SECTION 010000 – GENERAL REQUIREMENTS

PART 1 - GENERAL

1.1. INTENT AND ARRANGEMENT OF DOCUMENTS

A. THESE SPECIFICATIONS AND DRAWINGS are intended to include everything necessary to perform the entire work properly. Every item necessarily required may not be specifically mentioned or shown. Unless expressly stated, all systems and equipment shall be complete and operable.

B. TITLES AND HEADINGS to Divisions, Sections and paragraphs in these Subcontract documents are introduced for convenience and shall not be taken as a correct or complete segregation of the several units of materials and labor. No responsibility either direct or implied is assumed by the University or the Project Manager for omissions or duplications by the Subcontractor or the Subcontractor's Lower-tier Subcontractors, due to real or alleged error in arrangement of matter in the Subcontract documents.

C. THE TERMS of the Agreement, General Provision for Fixed Price Construction, and General Requirements apply to each Division of these Specifications as fully as if repeated within that Division.

D. ITEMS LISTED under Scope of Work for each Division of the Specifications are not necessarily all inclusive. The Subcontractor shall be responsible for the complete job.

E. PORTIONS OF THESE Specifications are of the abbreviated, simplified type and may include incomplete sentences.

1. Omissions of words or phrases such as: the Subcontractor shall, in conformity with, shall be, as noted on the drawings, in accordance with details, a, the, and all are intentional. Omitted words or phrases shall be supplied by inference in the same manner as they are when a note occurs on the drawings.

2. Such terms as: approved, reviewed, equal, as directed, as required, as permitted, acceptable, and satisfactory mean by or to the Architect/Engineer or Project Manager.

1.2. DEFINITIONS AND STATUS OF INDIVIDUALS

A. The terms defined in the agreement, general conditions, and general provision for fixed price construction shall apply throughout. Certain additional terms and refinements shall apply as specified below.

B. Subcontractor: The term "Subcontractor" shall mean the person or firm responsible for the execution of this Subcontract, or any portion thereof. This shall include the General or Prime Subcontractor, all Lower-tier Subcontractors and any suppliers. Subcontractor usually refers to the particular contractor concerned with the Section in which the term is found, but this in no way relieves the General Subcontractor of its sole responsibility for completing the entire work of this Subcontract.

1. The Subcontractor shall complete the work in accordance with the Subcontract Documents, approved submittals that comply with the Subcontract Documents, and any clarifications or instructions issued by the Project Manager. The Subcontractor shall not be relieved of any responsibility to comply with such requirements by the activities of the Architect/Engineer or the Project Manager.

C. Architect/Engineer: The term "Architect/Engineer" is the person or firm designated as the responsible design professional. The Architect/Engineer shall interpret and clarify the intent of the construction Subcontract Documents, and will participate with the University in determining the acceptability of workmanship, materials and the progress of the work, and entitlement to payment. The Architect/Engineer will review proposed changes, substitutions, shop drawings, and schedules submitted by the Subcontractor for approval as required by the Subcontract Documents. The Architect/Engineer shall have access to the work at all times and the authority to recommend that the University not accept any work or materials deemed not to conform to the requirements of the Subcontract.

1. The Architect/Engineer for the University is:

a. Company: [Name]

b. Address: [City/State only]

D. Project Manager: During the Construction Phase, all submittals and communications with the Architect/Engineer shall be through the University's "Project Manager". The Project Manager will administer the technical requirements of the Subcontract and will coordinate the inspection of the work. All professional design responsibility matters will be determined by the Architect/Engineer.

1. The Project Manager for the University is:

a. Jim Haslam, Project Manager
Lawrence Berkeley National Laboratory
1 Cyclotron Road, Mailstop 76R0225
Berkeley, California 94720
(510) 486-____
Jmhaslam@lbl.gov

E. Subcontract Administrator: The "Subcontract Administrator" is the University's representative responsible for administering the business and contractual requirements of the Subcontract. The Subcontract Administrator participates in change order negotiations and is the University's representative authorized to effect binding formal changes to the Subcontract as required.

1. The Subcontract Administrator for the University is:

a. Robert Kawamura, Subcontract Administrator
Lawrence Berkeley National Laboratory
1 Cyclotron Road, Mailstop 76R0225
Berkeley, California 94720
(510) 486-____
rkawamura@lbl.gov

1.3. CODES

A. Applicable provisions of Public Law 91-54, the Constitution and Laws of the State of California, and the codes and regulations of the Department of Energy are hereby referred to and made a part of this Subcontract. All work performed shall be in accordance with such laws, codes, and regulations. The latest edition or supplement or amendment thereto in effect at the time of submittal of bid shall be considered to be the issue in effect (unless shown otherwise) of all applicable laws, codes, and regulations including, but not limited to:

1. California Building Code (CBC)
2. California Electrical Code (CEC)
3. California Mechanical Code (CMC)
4. California Plumbing Code (CPC)
5. California Energy Code (CEC)
6. California Fire Code (CFC)
7. NFPA 70 National Electrical Code
8. General Services Administration 41 CFR Part 101-19
9. Americans with Disabilities Act (ADA)
10. Energy Conservation Performance Standards, 10 Code of Federal Regulations (CFR), Part 435 (Mandatory for Federal Buildings)
11. Codes and Standards listed in Division 01 Specification Section 013529, Environment, Safety, and Health Procedures.
12. Executive Order 13963 - Planning for Federal Sustainability in the Next Decade

B. Where codes or standard specifications other than those listed in this paragraph are referred to in the different Divisions of these specifications, it is understood that they apply as fully as if cited here.

C. Where differences exist between codes affecting this work, the code affording the greatest protection to the University shall govern.

D. If the Subcontractor observes that these drawings and specifications are at variance with the codes, the Subcontractor shall notify the Project Manager in writing at once for resolution.

E. Pursuant to Labor Code 6707, the Subcontractor shall include in its base bid all costs for provision of adequate sheeting, shoring, bracing, or equivalent method for the protection of life or limb, in conformance with applicable Federal and State safety orders.

F. Maintenance clearances shall be maintained around equipment as required by the plans and specifications and/or Codes and Standards, and as recommended by the equipment manufacturers. The maintenance envelope and equipment access shall be kept clear of any permanent obstruction. It is the Subcontractor’s responsibility to enforce

these requirements with all Lower-tier Subcontractors. The Subcontractor and Lower-tier Subcontractors shall be responsible for correcting any infringement on this requirement at no cost to the University.

1.4. CONSTRUCTION LIMITS

A. The area to be set aside for the work under this Subcontract is shown on the drawings, and the Subcontractor shall confine the construction to the immediate area within the construction limits.

1.5. PARKING—THE USE OF ROADS—SITE ACCESS

A. PARKING: Parking for private vehicles is limited. Parking for Subcontractors and their workers will be limited to the construction limits and as agreed with the Project Manager. During periods of underutilization, Lawrence Berkeley National Laboratory (Berkeley Lab, LBNL) personnel will be allowed to use Subcontractor parking spaces. Parking regulations will be strictly enforced and all parking violations are subject to citation by the University of California Police Department.

B. USE OF ROADS: The Subcontractor may use certain University roads as designated by the University for the transportation of equipment, materials, workers, or other needs related to the work of this Subcontract. The Subcontractor shall be responsible for all damage to roads, curbs, gutters, fences, guard rails, and other property resulting from Subcontractor use of the roads, and shall repair all damage resulting from such use.

C. SITE ACCESS: Heavy and slow-moving vehicles that impact the flow of traffic will not be permitted to enter LBNL from Hearst Avenue/Cyclotron Road or Centennial Drive between 7:00 a.m. and 8:30 a.m. on business days without written permission from the Project Manager. Requests to allow heavy and slow-moving vehicles to enter LBNL during this period shall be submitted to the Project Manager seven (7) calendar days in advance.

D. Permission for access to the site may be revoked for any and all persons who violate the University traffic regulations including speed limits, parking restrictions, and directions of the University Police. All of the Subcontractor's personnel, operating forces, and delivery personnel shall be made aware of and shall comply with traffic regulations at all times.

1.6. WORKING HOURS

A. Unless otherwise noted, construction operations shall be limited to the hours between 7:30 a.m. and 6:00 p.m., Mondays through Fridays, except for holidays. A request must be made to the University forty-eight (48) hours in advance for approval of work days or hours other than those stated above.

B. Compliance is required with the City of Berkeley Noise Ordinance to maintain sound levels at the LBNL perimeter created by the project below maximum levels as follows:

Days	Times	Maximum Decibels Level
Monday - Friday	7:00 am to 7:00 pm	80
Saturday, Sunday, & Holidays	9:00 am to 8:00 pm	65

1.7. COORDINATION OF WORK

A. The Subcontractor shall coordinate and schedule the work of all its Lower-tier Subcontractors, and shall furnish all information required by them for proper scheduling and execution of the work.

B. In the same manner, the Subcontractor shall coordinate the work with that of the University, and any other Subcontractor operating in the area, including reasonable adjustments of schedule in order to allow other Subcontractors or the University to do their work.

C. The University shall have the right to make final and binding decisions on disputes between the Subcontractor and any other Subcontractor operating in the area regarding:

1. Access to the site with work force, equipment, and/or materials to their work area.

2. Their adjacent work areas.

D. The Subcontractor shall immediately inform the Project Manager of the name of the person(s) designated as Superintendent representing the Subcontractor at the site. Once assigned, the Superintendent cannot be changed without the consent of the Project Manager.

1.8. INFORMATION TRANSMITTAL

A. The Subcontractor shall submit to the Project Manager the information and documents as described in the following Paragraphs B through I inclusive.

B. LIST OF LOWER-TIER SUBCONTRACTORS:

1. Within ten (10) calendar days following the Date of Notice to Proceed, the Subcontractor shall submit a list of all Lower-tier Subcontractors shown in the submitted bid documents for approval by the Project Manager. This list shall include the telephone numbers, addresses, license number, class, and portion of work to be accomplished.

2. Before the substitution of any Lower-tier Subcontractor listed in the bid form, the Subcontractor shall obtain consent from the University.

C. COST BREAKDOWN

1. PROGRESS PAYMENTS

a. Within ten (10) calendar days following the Date of Notice to Proceed, the Subcontractor shall submit a segregation of the Subcontract price itemizing the estimated cost of each class of work. Each item shall include a pro rata allowance for profit and overhead expense. Insurance and bond expense shall not be prorated but should be shown as separate items. The total of the items shall equal the Subcontract price. This segregation, when accepted by the Project Manager, shall become the basis for determining progress payments.

D. SCHEDULE OF OPERATIONS

1. GENERAL

a. The Subcontractor shall, within ten (10) calendar days after the effective date of Notice to Proceed, provide three (3) copies of a preliminary construction progress schedule covering Subcontractor operations for the first forty-five (45) calendar days. The preliminary progress schedule shall be a bar graph or an arrow diagram showing the times the Subcontractor intends to commence and complete the various work stages, with operations and contract items planned to start during the first forty-five (45) calendar days.

b. Within thirty (30) calendar days after the effective date of Notice to Proceed, the Subcontractor shall provide three (3) copies of a critical path method (CPM) network diagram (the Master Construction Schedule) as specified in Division 01 Specification Section 013500, Special Procedures, Paragraph 3.4, CPM Network Diagram. The diagram shall show the order in which the Subcontractor proposes to accomplish the work.

c. The Subcontractor and or their designated Commissioning Coordinator/Scheduler shall provide a detailed commissioning schedule within the Master Construction Schedule that includes all systems, required tasks/activities inclusive of necessary permits, work tasks, safety compliance steps, etc., within thirty (30) days of bid award to the University.

d. The CPM network diagram shall show interdependence and duration, along with installation man hours by craft of each activity. Any work element longer than fifteen (15) days shall be broken down into component parts. The critical path and float for each activity shall also be shown. The diagram or bar chart shall be neatly lettered and legibly drawn to a time scale.

e. After the initial submittal, the Subcontractor shall update the schedule monthly by entering actual progress for the period and submit five (5) copies as part of the monthly progress payment request.

f. Formal requests for utility shutdowns shall be in accordance with Division 01 Specification Section 013500, Special Procedures, Paragraph 1.6, Shutdown, and shall state the maximum duration of the shutdown.

2. DETERMINATION AND EXTENSION OF SUBCONTRACT TIME

a. The number of calendar days allowed for completion of work included in the Subcontract is stated in the proposal and Subcontract and shall be known as "Contract Time."

b. No changes shall be made to scheduled completion date(s) without prior approval by the Project Manager and the Subcontract Administrator. Extensions of time to the Subcontract can only be made by formal change order/Subcontract modification.

c. The Subcontractor shall submit to the Project Manager such justification, data, and other supporting evidence necessary for a determination as to whether or not the Subcontractor is entitled to an adjustment in completion date under the Subcontract. If the Subcontractor fails to submit sufficient evidence in support of the request, the Project Manager shall so inform the Subcontractor in writing. The Subcontractor may either submit additional evidence that, in the opinion of the Project Manager, is sufficient to determine the validity

of the request, or elect to have the Project Manager base the decision on the evidence previously submitted. The Subcontractor may not request or be given an adjustment in Subcontract time or any additional compensation for any delays if the Subcontractor fails to submit sufficient evidence to the Project Manager in support of this request within five (5) business days.

d. The Subcontractor shall submit to the Project Manager evidence in support of its time extension request based on revised activity duration, shown on the schedule. This schedule shall include or be accompanied by a sketch showing all revisions and duration changes for the work in question and its relationship to other activities on the approved arrow diagram. The schedule must clearly display that the Subcontractor has used, in full, all the float time available for the work involved in the request, or the Project Manager shall not grant the request. As used in this provision, the term "float time" means the amount of time that an activity can be delayed without affecting the date for completing the remaining Subcontract work.

e. The adjustment in contract time, if any, will be made at the sole discretion of the Project Manager and by the Subcontract Administrator, and will be based upon an evaluation of the current calendar-dated schedule in effect at the time of the alleged delay, the supporting evidence submitted by the Subcontractor, and any other available information deemed relevant by the Project Manager. Actual delays in activities that do not affect the extended and predicted Subcontract completion (shown by the critical path in the network diagram) will not be the basis for a change in the Subcontract completion date. If the Project Manager grants a date adjustment, the date, as adjusted, shall be in full force and effect thereafter as though it were the original Subcontract time. The adjusted date also shall be included in the data through the next monthly updating of the diagram and schedule.

E. MATERIALS AND EQUIPMENT

1. The Subcontractor shall submit a complete list of all materials and equipment to be incorporated in the work. Unless a specific time limit for this submittal is established within the provisions of these Specifications, this shall be done with such promptness as not to cause delay to the work.

2. All materials and equipment shall be new and within one year of manufacture. No rebuilt, refurbished, remanufactured, or used equipment and materials shall be installed under this project.

3. All project materials shall be furnished in accordance with the Buy American Act, FAR clause 52.225-9. Requests for waivers per this clause should be submitted with the bid documents.

4. SPECIFIED ITEMS – SUBSTITUTES

a. Wherever catalog numbers and specific or trade names followed by the designation "or equal" are used in conjunction with a designated material, product, thing, or service mentioned in these Specifications, they are used to establish the standards of quality, utility, and appearance required. Substitutions which are equal in quality, utility, and appearance to those specified will be approved, subject to the following provisions:

1) All Substitutions must be accepted by the Architect/Engineer in writing. For this purpose, the Subcontractor shall submit to the Project Manager, within thirty-five (35) calendar days after the Date of Commencement specified in the Notice to Proceed, a typewritten list containing a description of each proposed substitute item or material. The Project Manager may increase the submittal period beyond thirty-five (35) calendar days if the schedule allows. Sufficient data, drawings, samples, literature, or other detailed information as will demonstrate to the Architect/Engineer that the proposed substitute is equal in quality, utility, and appearance to the materials specified shall be appended to this list. The Architect/Engineer will accept, in writing, such proposed substitutions as are in his or her opinion, equal in quality, utility, and appearance to the items or materials specified. Such acceptance shall not relieve the Subcontractor from complying with the requirements of the drawings and specifications, and the Subcontractor shall be responsible at the Subcontractor's own expense for any changes resulting from Subcontractor proposed substitutions which affect the other parts of the Subcontractor's own work or the work of others.

2) Failure of the Subcontractor to submit proposed substitutions for approval in the manner described above and within the time prescribed shall be sufficient cause for disapproval by the Architect/Engineer of any substitutions otherwise proposed or installed.

3) If specified items are listed in the following format or similar format:

a) "First manufacturer and model number, equivalent second manufacturer or second manufacturer, or equal" the Subcontractor wishing to submit any "equivalent names manufacturer" shall do so in accordance with this SPECIFIED ITEMS-SUBSTITUTES provision.

b. Wherever catalog numbers and specific brands or trade names are not followed by the designation "or

equal," or used in conjunction with a designated material, product, thing, or service mentioned in these specifications, no substitution will be approved.

c. On Subcontracts with a short performance time, the thirty-five (35) day submittal period does not excuse the Subcontractor from completing the project within the performance time stipulated in the agreement or excuse the Subcontractor from the payment of liquidated damages if completion is late.

F. SUBMITTALS: Shop drawings and submittal data consisting of brochures, catalogs, materials lists, samples, and letters requesting review of materials or substitutions by the Subcontractor shall be submitted for review as follows (refer to Paragraph 1.8.H for Operation and Maintenance Data).

1. GENERAL

a. Within thirty (30) calendar days from Notice to Proceed (fifteen (15) days if the construction period is less than sixty (60) days), the Subcontractor shall submit one (1) electronic file with a complete listing of all equipment/material submittals, inspections, tests, and certifications required in accordance with the contract technical specifications to the Project Manager. The Subcontractor and Project Manager will utilize the list of inspections, tests, and certifications for tracking that all inspection, testing, and certification requirements were met for ensuring quality and acceptance criteria of the work.

b. When required by the technical specifications, the Subcontractor shall submit electronic files and five (5) prints of all shop drawings, erection drawings, and equipment layouts, and seven (7) copies of all vendor data for review by the Architect/Engineer. Submittals shall be processed with such promptness as not to cause delay to the work or to that of any Subcontractor or Lower-tier Subcontractor.

c. The Subcontractor shall be responsible for and shall check the correctness of all documents including those from Lower-tier Subcontractors prior to submitting them to the Project Manager for review.

d. The Project Manager will review and process shop drawings and other required submittals with reasonable promptness. No delay will be allowed in the progress of the job attributable to the Subcontractor's failure to make required submittals within a reasonable length of time.

e. The Architect/Engineer's favorable review of shop drawings and other submittals shall not relieve the Subcontractor of responsibility for deviations from drawings or specifications, unless the Subcontractor has in writing called the Architect/Engineer's attention to such deviations at the time of submission, and the Architect/Engineer has acknowledged in writing such deviations; nor shall it relieve the Subcontractor from responsibility for errors of any sort in such drawings.

f. If deviations, discrepancies, or conflicts between shop drawing submittals and the drawings and specifications are discovered either prior to or after the shop drawing submittals are reviewed by the Architect/Engineer, the drawings and specifications shall control and shall be followed.

g. The Subcontractor shall furnish prints of the favorably reviewed final shop drawings, erection drawings, equipment layouts, and vendor data to Lower-tier Subcontractors and suppliers for the proper coordination of their work. The Subcontractor shall keep one (1) complete set of the above documents at the job site for the use of the University and the Architect/Engineer.

2. PROCEDURE

a. Shop drawings and submittal data shall be submitted in accordance with technical specifications and as directed by the Project Manager. Each submittal shall be provided together with a transmittal letter or form. Each original transmittal shall be assigned a transmittal number. The number shall begin with the first initial of the name of the Subcontractor's firm followed by a serial number. Resubmittals shall indicate the original transmittal number with a numerical suffix in sequence. Each transmittal shall itemize the enclosures and indicate the distribution of the transmittal and the enclosures.

3. SHOP DRAWINGS

a. The Project Manager will return the marked and stamped drawings together with transmittal letter or form to the Subcontractor. If resubmittal is required, the Architect/Engineer will so note and the Subcontractor shall make another submission for review after correction resolving the review comments on the prior submittals.

b. The above procedure shall be repeated until the submittal is favorably reviewed by the Architect/Engineer.

c. The Subcontractor, upon receipt of the favorably reviewed drawings, shall provide and transmit copies to the Lower-tier Subcontractor and/or materials supplier as required, prior to proceeding with the work on the jobsite.

d. Prior to completion of the entire project, the Subcontractor shall submit one (1) set of favorably reviewed

shop drawings to the Project Manager for the record.

4. DATA: Product Data consisting of brochures, catalogs, materials lists, letters, manufacturers' installation instructions, etc. shall be submitted as described under Paragraph 1.8.E., Materials and Equipment, specific requirements of the Sections of the technical specifications, and as directed by the Project Manager. Items for use on this project shall be clearly indicated. Information which is not pertinent shall be voided.

   a. The Subcontractor shall transmit one (1) electronic file and five (5) hard copies to the Project Manager.

   b. The Project Manager will return one (1) approved electronic file and one (1) stamped copy to the Subcontractor together with transmittal letter/form to the Subcontractor. If resubmittal is required, the Architect/Engineer will so identify, and the Subcontractor shall make another submission for review after correction resolving the review comments on the prior submittals.

   c. The above procedure shall be repeated until the submittal is favorably reviewed by the Architect/Engineer.

   d. The Subcontractor, upon receipt of the favorably reviewed submittal data, shall provide and transmit the data to the Lower-tier Subcontractor and/or materials supplier as required prior to proceeding with the work on the jobsite.

   e. Prior to completion of the entire project, the Subcontractor shall submit one (1) copy of favorably reviewed product data to the Project Manager for the record.

G. RECORD DRAWINGS

1. The Subcontractor shall maintain at the site a complete, precise, accurate, dimensioned record of actual locations of the work, including concealed and embedded work, size and type of equipment, and every change or deviation from original Subcontract Drawings. The Subcontractor shall keep this record legible and correct weekly as the job progresses on black or blueline prints. The Subcontractor shall keep Record Drawings available for inspection at all times. Record Drawings will be inspected before approval of requests for payment.

2. It shall be the responsibility of the Subcontractor to submit to the Project Manager within ten (10) days after final inspection, one (1) complete marked-up set of Subcontract drawings fully illustrating all revisions made by all the crafts in the course of the work. This shall include all field changes, adjustments, variances, substitutions and deletions, whether covered by Change Order or not. Underground utility installations must be located precisely as constructed on the marked-up drawings.

H. OPERATION AND MAINTENANCE DATA

1. PROCEDURE

   a. The equipment specific Operation and Maintenance (O&M) manuals shall be submitted no later than fifteen (15) business days from equipment delivery. Equipment and material data sheets (mechanical and electrical) shall be submitted no later than fifteen (15) business days from equipment delivery. Forms for data sheets can be found in equipment specific Specification Divisions.

   b. Draft: Submit one (1) electronic file and one (1) hard copy of draft of completed volumes. This copy will be reviewed by the University and returned to the Subcontractor with comments. The Subcontractor/Lower-tier Subcontractor will revise content of all document sets as required prior to final submission.

   c. Final: Submit one (1) electronic file and two (2) sets of revised final volumes within ten (10) days after final inspection. The final electronic manual shall be in a searchable format, logically organized as described below. The electronic file name shall include the project name, equipment name, and equipment number.

   d. Submit hard copy data in the following format:

      1) Bind in 8-1/2 x 11 inch (A4) text pages, three (3) D-ring binders with durable plastic covers.

      2) Prepare binder cover with printed title "OPERATION AND MAINTENANCE INSTRUCTIONS", title of project, and subject matter of binder when multiple binders are required.

      3) Internally subdivide the binder contents with permanent page dividers, logically organized as described below; with tab titling clearly printed under reinforced laminated plastic tabs.

2. CONTENTS: Prepare a Table of Contents for each volume, with each product or system description identified, typed on 24 pound white paper, in three (3) parts as follows:

   a. Part 1: Directory, listing names, addresses, and telephone numbers of Architect/Engineer, Contractor, Subcontractors, and major equipment suppliers.

b. Part 2: Operation and maintenance instructions, arranged by system and subdivided by specification section. For each category identify names, addresses, and telephone numbers of Subcontractors and suppliers. Identify the following:

1) Significant design criteria.

2) List of equipment (including assigned equipment numbers).

3) Parts list for each component.

4) Operating instructions.

5) Maintenance instructions for equipment and systems.

6) Maintenance instructions for finishes, including recommended cleaning methods and materials, and special precautions identifying detrimental agents.

c. Part 3: Project documents and certificates, including the following:

1) Product data.

2) Completed equipment data sheet for each piece of equipment.

3) Air and water balance reports.

4) Certificates.

5) Photocopies of warranties (with final O&M manuals).

I. GUARANTEE

1. All work shall be guaranteed for one (1) year from the date of acceptance against all defects in materials, equipment, and workmanship.

2. When required by individual Specification Sections, guarantees for specific items shall be for periods longer than one (1) year.

3. The Subcontractor shall submit guarantees prior to the date of final completion and prior to final application for payment. Provide three (3) original copies.

4. The Subcontractor shall provide a hard copy of all guarantees in one binder and an electronic file in PDF format. At the beginning of the binder, the date of substantial completion shall be indicated to reflect the start date of the one (1) year guarantee period.

5. FORM OF GUARANTEE

a. All guarantees shall follow the format contained in Attachment A at the end of this Section.

b. All guarantees shall be provided on the letterhead of the Subcontractor, Lower-tier Subcontractor, or Supplier doing the work or supplying the item guaranteed.

1.9. FINAL ACCEPTANCE

A. Notice that the work is ready for final inspection and acceptance shall consist of a written notice issued to the Project Manager by the Subcontractor stating that the Subcontractor has carefully inspected all portions of the work, has reviewed in detail the drawings and specifications, and that to the best of the Subcontractor's knowledge all requirements and conditions of the Subcontract documents have been fulfilled.

B. Upon receipt of this notice, the Project Manager and the Subcontractor shall make a joint inspection of the work. After deficiencies, if any, have been corrected or accounted for, and after all work is satisfactorily complete, the University will accept the work; and Notice of Completion will be filed by the University.

C. Prior to final acceptance, filing of the Notice of Completion or processing of final payment, the following documents shall be submitted, reviewed, and accepted by the University and the Architect/Engineer:

1. Certificates of compliance and guarantees required under various Sections.

2. Record Drawings: Per Paragraph 1.8.G.

3. Operating and maintenance manuals.

4. Instruction of University personnel, as required.

5. All required operations tests.

1.10. PRIORITIES, ALLOCATIONS AND ALLOTMENTS

A. The Subcontractor shall follow the provisions of DMS Regulation 1 and all other applicable regulations and orders of the Domestic and International Business Administration, Department of Commerce, in obtaining controlled materials and other products and materials needed to complete this Subcontract.

1.11. SUBCONTRACTOR'S LICENSE

A. Specialty contractors bidding as prime contractors must comply with Business and Professions Code 7059. If a specialty contractor submits a prime bid covering the performance of work involving two or more specialized building trades or crafts, which "other" work is more than incidental and supplemental to the performance of construction for which the prime bidder holds a specialty license, the prime bidder must also hold either (1) specialty licenses in each craft or trade which is more than incidental to the construction to be performed, or (2) an "A" General Engineering License, or (3) a "B" General Building License. The foregoing rule is applicable whether or not the prime bidder lists licensed specialty contractors for such "other" work.

B. All work involving fire sprinkler systems shall be performed by a contractor possessing a valid State of California C-16 License.

1.12. CHANGE ORDERS

A. In connection with change orders under this Subcontract, not covered by unit price or alternate bids, the University will use the following formulas for approval unless it determines that such amounts would not be acceptable. All estimates must be itemized to show the separate costs of labor and materials and other costs as described below for each item of work.

B. For work performed by the Subcontractor, the estimated cost of the work which includes the direct cost of labor, materials, supplies, and transportation plus fifteen percent (15%) of such estimated costs for overhead and profit to which shall be added payroll taxes, sales tax, applicable insurance and bond costs.

C. For work performed by a first-tier Subcontractor of the Subcontractor, the basis shall be as established in the preceding paragraph to which the Subcontractor may add five percent (5%) to such estimated costs plus any applicable bond or applicable insurance charges.

D. For work performed by a second-tier Subcontractor of the Subcontractor, the basis for payment shall be as for a first-tier Subcontractor except that the first-tier Subcontractor may add five percent (5%) of the second-tier Subcontractor's total estimated costs as overhead and profit and the Subcontractor may add five percent (5%) to the preceding estimated costs. No increases for overhead and profit will be allowed above the fifteen percent (15%) and five percent (5%) and five percent (5%) herein provided regardless of the number of tiers of Subcontractors involved.

E. For deletions not covered by unit prices or alternate bids, the Subcontractor agrees that the University shall be credited with the estimated cost of the labor, materials, supplies, transportation, payroll taxes, sales taxes, insurance, bond costs, overhead, and profit that would have been incurred in connection with the work omitted had it not been omitted.

PART 2 - PRODUCTS NOT USED

PART 3 - EXECUTION NOT USED

END OF SECTION 010000

ATTACHMENT A

GUARANTEE

Project Name: _____ Date: _____

Project Location: _____

Project Number: _____

Guarantee For: _____
(Specification Section and Contract No.)

(the "Contract"), between University ("Owner") and _____ ("Contractor").

_____
(Name of Contractor, Subcontractor, or Supplier as Applicable)
hereby guarantees to Owner that the portion of the Work described as follows:

_____

_____

_____
which it has provided for the above referenced Project, is of good quality; free from defects; free from any liens, claims, and security interests; and has been completed in accordance with Specification Section _____ and the other requirements of the Contract.

The undersigned further agrees that, if at any time within _____ months after the date of the guarantee the undersigned receives notice from Owner that the aforesaid portion of the Work is unsatisfactory, faulty, deficient, incomplete, or not in conformance with the requirements of the Contract, the undersigned will, within ten (10) calendar days after receipt of such notice, correct, repair, or replace such portion of the Work, together with any other parts of the Work and any other property which is damaged or destroyed as a result of such defective portion of the Work or the correction, repair, or replacement thereof; and that it shall diligently and continuously prosecute such correction, repair, or replacement to completion.

In the event the undersigned fails to commence such correction, repair, or replacement within ten (10) calendar days after such notice, or to diligently and continuously prosecute the same to completion, the undersigned, collectively and separately, do hereby authorize Owner to undertake such correction, repair, or replacement at the expense of the undersigned; and Contractor will pay to Owner promptly upon demand all costs and expenses incurred by Owner in connection therewith.

SUBCONTRACTOR OR SUPPLIER (If Applicable)

Signed: _____ Title: _____

Typed Name: _____

Name of Firm: _____

Contractor License Classification and License Number:

_____

Address: _____

Telephone Number: _____

CONTRACTOR

Signed: _____ Title: _____

Typed Name: _____

Name of Firm: _____

END OF ATTACHMENT A

SPECIFICATIONS SECTION 019113 – GENERAL COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.1. SUMMARY

A. Related Documents:

1. Drawings and general provisions of the Subcontract apply to this Section.
2. Review these documents for coordination with additional requirements and information that apply to work under this Section.

B. It is of primary concern that all systems and assemblies in the project perform in accordance with the design intent and the University's operational needs. The process of assuring that such performance is achieved is referred to as "commissioning."

C. Commissioning requires cooperation and direct involvement by all parties throughout the construction process. Successful commissioning requires that installation of all building systems and assemblies not only comply with contract requirements but also that it is achieved early enough in the construction phase to provide full operational check-out, testing and adjustments prior to Substantial Completion. In addition to fulfilling scheduling and planning requirements, the Trade Subcontractors are further responsible for documenting the equipment and system installation and operational verification for all systems and assemblies.

D. The CMGC and Trade Subcontractors are responsible for commissioning as defined herein. The University will provide a third party Commissioning Authority as defined herein. The CMGC shall provide a Commissioning Coordinator to lead the Subcontractor’s efforts throughout the commissioning process.

E. This Section includes a description of the commissioning process to be used for this Project and applies to all commissioned systems and assemblies.

F. Overall Quality Assurance/Quality Control (QA/QC): Quality assurance and quality control on this Project shall be accomplished by the following, as specified. Not all elements are monitored by the commissioning process.

1. Submittal reviews of Shop Drawings and material descriptions and certifications.
2. Qualifications and approvals of certain specified sub-tier Contractors and testing agencies or laboratories.
3. Inspection, testing and certifications by agencies provided by the University, including on-site and laboratory testing.
4. Inspection, testing and certifications by agencies provided by the Trade Subcontractors, including on-site and laboratory testing.
5. Inspection and testing by regulatory agencies.
6. CMGC and Trade Subcontractor and University checks, inspections, tests and certifications.
7. Mock-ups and evaluations.
8. Commissioning: Commissioning enhances installation and setup and verifies the functional performance of the more dynamic systems through observation and testing as specified in this Section. Commissioning also may cover the QA/QC of certain static building elements or assemblies. Some QA/QC activities will be overseen by the commissioning process, while other QA/QC activities will be overseen by the CMGC, the Architect or University. Generally, the QA/QC activities that have traditionally been conducted in the past remain outside the formal commissioning umbrella, such as concrete testing, inspection of static building elements, and regulatory or code inspections. However, compiling the documentation of some of these traditional activities may be within the commissioning scope, as specified herein.

G. Commissioning Process Overview: The following narrative provides a brief overview of the typical commissioning tasks during construction and the general order in which they occur.

1. Commissioning during construction begins with a planning meeting followed by a kick-off meeting conducted by the Commissioning Authority where the commissioning process is planned and reviewed with the commissioning team members.
2. Additional meetings will be required throughout construction, scheduled by the PM for the Commissioning Authority with necessary parties attending, to plan, scope, coordinate, schedule future activities and resolve problems.

3. Equipment and assembly documentation is submitted to the University and their Commissioning Authority during normal submittals, including detailed start-up procedures and early copies of Operation and Maintenance (O&M) data, upon receipt of equipment to be installed on the project.
4. The Trade Subcontractor develops start-up plans for selected equipment with review by the Commissioning Authority. The Commissioning Authority reviews the Trade Subcontractor developed construction checklists that are completed by the Trade Subcontractor during the start-up process. Responsibilities among parties are summarily listed in Supplement 3 to this section.
5. In general, the checkout and performance verification proceeds from simple to complex; from component level to equipment to systems and intersystem levels with construction checklists being completed before testing.
6. The Trade Subcontractor(s), under the direction of the Subcontractor's designated Commissioning Coordinator in accordance with the OEM equipment manual /system design that they installed as part of the project, execute and document the construction checklists and perform start-up and initial checkout.
7. The Commissioning Authority documents that the checklists and start-up were completed through spot witnessing and review Trade Subcontractor's completed checklists and startup reports. Daily written/photo copy updates will be provided for commissioning status to the Commissioning Authority and University by the General Contractor and or their designated Commissioning Coordinator of their subcontractor(s). The documents shall be signed by the representative installing Trade Subcontractor (equipment start-up (OEM) and or Controls contractor (program point to point checklist) and submitted to the Commissioning Authority and University prior to functional performance testing.
8. The General Contractor and/or their designated Commissioning Coordinator will report in the daily commissioning meetings per the schedule of all commissioning steps for all systems as part of the project. The General Contractor and or their designated Commissioning Coordinator will provide for in advance of the meetings in direction to their subcontractors for solutions and resolutions to late material deliveries, service vendor coordination, equipment replacement/ repairs for non-compliance and/or failures, etc. to maintain schedule of commissioning.
9. The Subcontractor and or their designated Commissioning Coordinator will provide a detailed schedule within the Master Construction Schedule that includes all systems, required tasks/activities inclusive of necessary permits, work tasks, safety compliance steps, etc., by the mid-point of construction to the University and the Commissioning Authority (examples provided upon request). All University and Commissioning Authority comments and concerns will be addressed by the General Contractor and the General Contractor will be wholly responsible for all discrepancies, missed items, etc. and shall address and rectify them immediately at their expense.
10. The Commissioning Authority performs periodic construction observation.
11. The Commissioning Authority develops specific written equipment, system and assembly test procedures for all commissioned equipment. The procedures will include the expected/desired results.
12. The test procedures are executed by the Trade Subcontractor, under the direction of the General Contractor and or designated Commissioning Coordinator in accordance with and documented by the Commissioning Authority for most equipment. Selected testing is directed and documented by the Trade Subcontractor (see Supplement 3 to this Section).
13. Items of non-compliance in material, installation or setup are corrected by the Trade Subcontractor and the system is re-tested.
14. The Commissioning Authority reviews the O&M manuals for clarity, accessibility and completeness that are specific to the equipment installed as part of the project.
15. The Commissioning Authority reviews, pre-approves and coordinates the training provided by the Trade Subcontractor and verifies that is was completed.
16. Commissioning shall be completed before Substantial Completion inclusive of 7/24 hour test(s), except for trend log monitoring, seasonal testing, near-warranty end activities, verification of later controls system training sessions, and review of final red-line drawings.
17. Opposite season or deferred testing and near-warranty-end activities are conducted, as specified.

H. Design phase reviews, not commissioning during construction, ensure that any given feature qualifies for a Leadership in Energy and Environmental Design (LEED) credit. Gathering LEED required documentation is not part of the commissioning scope of this Project, other than for the commissioning credit itself. All required documentation and procedures to comply with LEED Energy and Atmosphere commissioning prerequisite and the additional point

are included in the commissioning scope.

I. LEED requires that all features in the Water Efficiency and in the Energy and Atmosphere and most of the Indoor Environmental Quality areas are appropriately commissioned. The following equipment, systems, assemblies and features will be commissioned utilizing the traditional construction phase commissioning process that includes submittal review, construction checks, testing, observation, and training and documentation verification. All general references to equipment in this document refer only to equipment that is to be commissioned. The responsibility for developing and reviewing forms, overseeing, documenting and witnessing execution and reviewing reports of checks and tests is distributed among constructors, designers and University parties and differs for different equipment types. The Check and Testing Responsibility Table (Supplement 3) included as a supplement to this Section lists these responsibilities.

1. HVAC and mechanical system and all integral equipment controls. All HVAC systems shall be commissioned, including, but not limited to:
    a. Chilled water system (chiller, cooling tower, filtration system, chemical treatment, piping, pumps)
    b. Heating water system (boilers, piping, pumps)
    c. Air handlers
    d. Hydronic piping (including air separators and expansion tanks)
    e. Ductwork
    f. Thermal comfort, temperature and humidity control
    g. Variable speed drives
    h. Air terminal boxes
    i. Fan coil units
    j. Restroom exhaust system
    k. Facilities Monitoring and Control System
    l. TAB work including 7/24 hr test(s)
    m. HVAC and envelope differential pressure relationships
    n. Fire protection system
2. Electrical Systems:
    a. Scheduled lighting controls
    b. Lighting occupancy sensors Emergency egress lighting
    c. Emergency power generator system. Load bank and ATS
    d. Fire alarm system
    e. Power and energy meters
3. Laboratory and Clean Room
    a. Cleanroom makeup air units
    b. Cleanroom fan filter units
    c. Cleanroom certification
    d. Fume hoods and snorkel exhaust
    e. Hood and process exhaust systems
    f. Laboratory pressure and temperature control
    g. Biological safety cabinets
    h. Safety cabinets
    i. Cold rooms
    j. TAB work

4. Process Mechanical
    a. Treated Water System
    b. Vacuum System
    c. Compressed Air Systems
    d. Bio-waste sterilization
    e. Biomedical prep and glass cleaning
    f. Pure water systems
    g. Process gas systems
    h. Process and M&P metering

J. The following static elements and features will be commissioned utilizing documented submittal review and observation, without testing: Details are given later in this Section.
    1. Static LEED Water and Wastewater Efficiency Features: Low flow faucet and shower aerators.
    2. Static LEED Energy Features:
        a. Exterior windows and doors.
        b. Envelope and pipe insulation.
    3. Static LEED Indoor Environmental Quality (IEQ) Features:
        a. IAQ management during construction and turnover.
        b. Envelope air and moisture control design and integrity.

K. Commissioning will be directed by the General Contractor and or their designated Commissioning Coordinator in accordance with the Commissioning Authority under the direction of the University.

L. Related Sections
    1. The General and Supplementary Conditions, applicable requirements of all Divisions of the Contract Specifications and all Contract Drawings apply to the work of this Section. In the event of conflict between specific requirements of the various documents, the more restrictive or extensive requirement shall govern.
    2. Specific commissioning requirements and related issues are given in the following Sections of the Specifications.
    3. Division 01, Section 010000, General Requirements: Submittals: Alerts Subcontractor to submittal requirements for commissioning.
    4. Division 01, Section 010000, General Requirements: Final Acceptance: Lists some commissioning tasks required for substantial completion and final acceptance.
    5. Division 01, Section 013513.13, Cleanroom Certification and Acceptance, Commissioning requirements for lab and clean room process equipment and systems.
    6. Division 23, Section 230800, Commissioning of HVAC: Special Mechanical system requirements and testing requirements by system.
    7. Division 26, Section 260800, Commissioning of Electrical Systems: Electrical component testing requirements.
    8. Division 01, Section 017900, Demonstration and Training: Training requirements.
    9. Division 01, Section 010000, General Requirements: O&M manual requirements.
    10. Division 23, Section 230500, Common Results for HVAC: Alerts Trade Subcontractor to commissioning in other sections.
    11. Division 26, Section 260500, Common Work Results for Electrical: Alerts Trade Subcontractor to commissioning in other sections.

1.2. DEFINITIONS

A. Active Test: Using hand-held instruments, immediate control system readouts or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the “observation”).

B. Approval: Acceptance that a piece of equipment, system or issue related to it complies with the Contract Documents.

C. Architect/Engineer: The prime consultant (Architect) and sub-consultants who comprise the design team, generally the HVAC mechanical designer/engineer and the electrical designer/engineer.

D. Basis of Design: See Design Basis.

E. Certified Testing Company: An industry certified company utilizing industry certified technicians on this project who will perform inspections and testing for equipment and systems. This company is not affiliated or owned by the equipment manufacturer.

F. Commissioning: Commissioning is a systematic process of ensuring that all building systems and assemblies perform interactively according to the University's objectives and requirements. This is achieved by beginning in the design phase and documenting the University's Project requirements and continuing through construction, acceptance and the warranty period with actual verification of function and performance. The commissioning process encompasses and coordinates the traditionally separate functions of system documentation, equipment start-up, control system calibration, testing and balancing, testing and training. The commissioning process does not take away from or reduce the responsibility of the system designers or installing Trade Subcontractors to provide a finished and fully functioning product. Commissioning during the construction phase is intended to achieve the following specific objectives:

1. Ensure that applicable equipment, systems and assemblies are installed according to the manufacturer's recommendations and to industry accepted minimum standards and that they receive adequate operational checkout by installing Trade Subcontractors.

2. Ensure and document that equipment, systems and assemblies function and perform according to the Contract Documents and the University objectives and requirements.

3. Ensure that O&M manuals are complete.

4. Ensure that the University operating personnel are adequately trained.

G. Commissioning Authority: An independent party, not otherwise associated with the A/E team members, CMGC or the Trade Subcontractors. The Commissioning Authority provides assurance to the University of the General Contractor's responsibility for compliance with the commissioning requirements per the contract documents and ensures the General Contractor and or their designated Commissioning coordinator coordinates the day-to-day commissioning activities in concert with the CMGC's schedule. The Commissioning Coordinator will lead the commissioning meetings in acquiring information from the General Contractor and or their designated Commissioning Coordinator regarding commissioning issues resolution, scheduling report status updates, status/completed checklists, status/completed test procedures etc. The Commissioning Authority will provide recommendations for as needed and or in accordance with the Project Manager in execution of the commissioning phase of the project.

H. Commissioning Plan: An overall plan, developed before or after bidding, that provides the structure, schedule and coordination planning for the commissioning process. The commissioning plan includes details of the commissioning scope; systems to be commissioned; rigor of commissioning; team contact information; roles and responsibilities of all players; communication and reporting protocols; commissioning process overview as well as details of submittal activities; construction observation, construction checklist and start-up activities; the process for dealing with deficiencies; test procedure development and execution; O&M manual review and training issues; warranty period activities; description of summary report, description of progress and reporting logs and initial schedule including phasing, if applicable. The Commissioning Authority updates the plan as construction progresses.

I. Contract Documents: The documents binding on parties involved in the construction of this Project (Drawings, Specifications, Change Orders, Addenda, Contracts, and Requests for Information).

J. CMGC: The Construction Manager/General Contractor or authorized representative.

K. Facilities Monitoring and Control System (FMCS): The central building energy management control system.

L. Construction Checklist: A list of items to include in the installation, start-up and initial checkout of a piece of equipment or assembly. Construction checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels, labels affixed, gauges in place, sensors calibrated, etc.). Some construction checklist items entail simple testing of the function of a component, a piece of equipment or system (such as measuring the voltage imbalance on a three phase pump motor of a chiller system). Construction checklists augment and are combined with the manufacturer's start-up checklist. An example is provided as supplement to this Section.

M. Datalogging: Monitoring flows, currents, status, pressures, etc., of equipment using stand-alone dataloggers separate from the control system.

N. Deferred Tests: Tests that are performed later, after substantial completion, due to partial occupancy, equipment, seasonal requirements, design or other site conditions that disallow the test from being performed.

O. Deficiency: A condition in the installation or function of a component, piece of equipment or system that is not in compliance with the Contract Documents (that is, does not perform properly or is not complying with the University's objectives).

P. Design Basis: The basis and assumptions for calculations, decisions, schemes and product selections to meet the University's Project requirements and objectives and to satisfy applicable regulatory requirements, standards and guidelines.

Q. Design Narrative: A narrative submitted with each design submittal describing the concepts and features in the Drawings. The Design Narrative is written by the designer and is updated and increases in detail with each phase of the design. Initially, it may describe general building and space use and later should include detailed space usage and system and assembly descriptions.

R. Design Record: The compilation of the following five elements: University Project Requirements, University Objectives, Design Narrative, Design Basis and Performance Metrics.

S. Documenting Tests: The recording of what actions were taken to perform each individual test procedure, along with the results or system response of the procedure, with any deficiencies noted.

T. Emergency Power and Fire Alarm Response Matrix: A matrix listing all equipment and components (air handlers, dampers, valves, fire doors, elevators, control system, security system, lighting, etc.) with their status and action after each fire alarm initiation type, under emergency power and the requirements to bring each system back on line.

U. Factory Testing: Testing of equipment on-site or at the factory by factory personnel with the University present.

V. Indirect Indicators: Indicators of a response or condition, such as a reading from a control system screen reporting a damper to be 100 percent closed.

W. Issues Log: Ongoing record of the issues identified during the commissioning process that require or did require correction. For each entry the log includes a unique identification number, identification date, identification party, a short description of the issue, the equipment or assembly it is associated with, a long description of the issue, including cause, implications of the issue, recommendations for correction, assignment of responsibility for correction, an issue closed date and the name of the party verifying the correction. The Commissioning Authority is responsible to maintain the log.

X. Manufacture's Service Representative (MSR): A company that is certified and trained by a manufacturer to provide startup, testing, and troubleshooting service for equipment.

Y. Monitoring: The recording of parameters (flow, current, status, pressure, etc.) of equipment operation using dataloggers or the trending capabilities of control systems.

Z. NETA: International Electrical Testing Association, Inc.

AA. Non-Compliance: See Deficiency.

BB. Non-Conformance: See Deficiency.

CC. Over-written Value: Writing over a sensor value in the control system to see the response of a system (e.g., changing the outside air temperature value from 50 degrees F to 75 degrees F to verify economizer operation). See also "Simulated Signal."

DD. University: The representative on the Project that has the authority to act in the University's behalf in all issues.

EE. University-Contracted Tests: Tests paid for by the University outside the CMGC's contract and for which the Commissioning Authority does not oversee. These tests will not be repeated during tests if properly documented.

FF. University Objectives: A distillation of the most salient concepts within the University's Project Requirements considered important to the University to have in writing and to be tracked through design and construction. The University Objectives are sometimes referred to as the design intent.

GG. University Project Requirements: Documentation of the functional requirements of the facility and the expectations of how it will be used and operated. This includes Project and design goals, measurable performance criteria, budgets and schedules and supporting information. This document is analogous to what has traditionally been referred to as the University Program.

HH. Performance Metrics/Benchmark: Measurable indicators that allow verification that a specific University Objective or Requirement or element in the Design Narrative has been met. Performance Metrics are identified throughout the

design of the Project with as many as possible being generated during the development of the University Objectives. Metrics are most applicable for those University Objectives that allow for a numerical quantitative evaluation. However, some University Objectives may have Performance Metrics that are not numerical.

II. Phased Commissioning: Commissioning that is completed in phases (by floors, for example) due to the size of the structure or other scheduling issues, in order minimize the total construction time.

JJ. Sampling: Functionally testing only a fraction of the total number of identical or near identical pieces of equipment.

KK. Seasonal Tests: Tests that are deferred until the system(s) will experience conditions closer to their design conditions.

LL. Simulated Condition: Condition that is created for the purpose of testing the response of a system (e.g., applying a hair blower to a space sensor to see the response in a VAV box).

MM. Simulated Signal: Disconnecting a sensor and using a signal generator to send an amperage, resistance or pressure to the transducer and DDC system to simulate a sensor value.

NN. Specifications: The construction Specifications of the Contract Documents.

OO. Start-up: The initial starting or activating of dynamic equipment, including executing construction checklists.

PP. Trade subcontractor: A sub-tier Contractor to the CMGC.

QQ. Systems Manual: A manual providing to the immediate and future operating staff the information needed to understand and optimally operate each system. The manual is in addition to the O&M Manuals submitted by the CMGC. The systems manual focuses on operating, rather than maintaining the equipment, particularly the interactions between equipment. Some components of the manual may reside in the CMGC-submitted O&M Manuals.

RR. Test: Assessments that verify specific components, assemblies, systems, and interfaces among systems function and perform in accordance with the University's objectives and the Contract Documents. Testing may include using manual (direct observation) or monitoring methods. Testing is the dynamic testing of specific and interacting equipment and systems in full operation. Tests are generally performed after construction checklists and start-up are complete. Some procedures in construction checklists test components, but reference to "testing" generally refers to those equipment and system tests conducted after Trade Subcontractor startup and initial checkout.

SS. Test Procedures (TP): The written procedures and documentation forms of tests used to guide and record testing. For mechanical systems, TPs are composed of repeatable, step-by-step procedures and include the test prerequisites, the test process, the expected outcomes and acceptance criteria. Forms or space for recording the results of tests may be included integrally in the written procedures or attached on separate sheets. For electrical component testing, the procedures may be less step-by-step-like than for dynamic mechanical equipment. For each piece of equipment, checks and test procedures and their documentation record forms may be different documents or combined in the same document, but checks and tests should be grouped. Responsibility for test procedure development is shared between the Commissioning Authority and the Trade Subcontractor according to the Check and Check and Testing Responsibility Table, attached as a supplement to this Section.

TT. Test Requirements: Requirements specifying what modes and functions, etc., shall be tested. The test requirements are not the detailed test procedures.

UU. Trending: Monitoring using the building control system.

VV. Vendor: Supplier of equipment.

WW. Warranty Period: Refer to Division 01, Section 010000, General Requirements, for a technical definition relative to equipment. For commissioning purposes and where referenced in a commissioning section, Warranty Period is defined as one year from substantial completion.

1.3. RESPONSIBILITIES

A. Overview: The responsibilities of the non-CMGC or Trade Subcontractor parties in the commissioning process are summarized in the following articles. It is noted that the services for the University, Architect, mechanical and electrical designers/Engineers, and Commissioning Authority are not provided for in this Contract. That is, the CMGC or Trade Subcontractor is not responsible for providing their services. Their responsibilities are listed here to clarify the commissioning process. Additional responsibilities of subcontractors to the CMGC are found in other Sections of Division 01, General Requirements.

B. Architect and Mechanical and Electrical Engineers of Record:

1. All tasks of the designers are applicable only if it is within their contracted scope of services.

2. Construction Phase:
    a. Review the Commissioning Plan.
    b. Attend the commissioning planning and kick-off meetings and selected commissioning team meetings.
    c. The mechanical and electrical engineer attend the controls integration meetings.
    d. Perform normal submittal review, construction observation, O&M manual review.
    e. With the Trade Subcontractors and Commissioning Authority, actively assist in the development of the emergency power and fire alarm response matrix.
    f. Review the coordination Drawings.
    g. Assist (along with the) in clarifying the operation and control of commissioned equipment in areas where the Specifications, control Drawings or equipment documentation is not sufficient for writing detailed testing procedures.
    h. Witness selected testing.
    i. Coordinate resolution of system deficiencies and warranty issues identified during commissioning.
    j. Provide an overview of system design and function during selected operator trainings.
    k. Provide design basis and design narratives documentation for the Systems Manual.
    l. Review Systems Manual.
3. Warranty Period: Coordinate resolution of design non-conformance and design deficiencies identified during warranty-period commissioning activities.

C. Commissioning Authority:
1. Construction Phase:
    a. The primary role of the Commissioning Authority is to develop and coordinate the execution of a process of improved equipment installation and checkout and to verify and document that systems are functioning in accordance with the documented objectives of the University and in accordance with the Contract Documents. The Commissioning Authority is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management, unless specifically stated otherwise in the Contract Documents. The Commissioning Authority may assist with problem-solving non-conformance or deficiencies, but ultimately that responsibility resides with the CMGC and Trade Subcontractors.
    b. Coordinate the commissioning work and with the CMGC to ensure that commissioning activities are being scheduled into the master schedule. The General Contractor and or their designated Commissioning Coordinator will provide a detailed schedule within the Master Construction Schedule that includes all systems, required tasks/activities inclusive of necessary permits, work tasks, safety compliance steps, etc by the mid-point of construction to the University and the Commissioning Authority.
    c. Revise, as necessary, the construction phase commissioning plan developed during design, including scope and schedule.
    d. Plan and conduct commissioning meetings including the planning and kick-off meetings as needed and distribute minutes.
    e. Request and review additional information required to perform commissioning tasks, including O&M materials, Trade Subcontractor start-up and checkout procedures. Before start-up, gather and review the current control sequences and interlocks and work with Trade Subcontractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.
    f. Equipment List Matrix.
        1) Develop an equipment list matrix of commissioned equipment in a computerized spreadsheet in a grouped and organized format.
        2) Include:
            a) Brief equipment or system name
            b) Tag or ID number

c) Governing specification section

d) Submittal reference number

e) Installation location by room number or coordinates

g. Track status of each piece of equipment in the equipment list matrix for: receipt of documentation, submittal reviewed, construction checklist development and execution progress, startup, test form development and execution, trend log completion, O&M manual submission, training agenda development or receipt and training completion, red-line document submission and opposite season testing.

h. Develop the format for, and coordinate the completion of the emergency power and fire alarm response matrix as defined in this Section.

i. Review normal Trade Subcontractor submittals applicable to systems being commissioned concurrent with the A/E reviews for compliance with commissioning and O&M manuals and coordination issues.

j. Review requests for information and change orders for impact on commissioning and University's objectives.

k. Review coordination Drawings and ensure that trades are making a reasonable effort to coordinate.

l. Review Trade Subcontractor's developed start-up and initial systems checkout plans with the Trade Subcontractors for selected equipment.

m. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.

n. Coordinate with the Architect to verify that any sustainable design requirements affected by system performance or commissioning are addressed.

o. Document construction checklist completion by reviewing completed construction checklists and by selected site observation.

p. Document systems start-up by reviewing start-up reports and by selected site observation.

q. Write step-by-step test procedures and documentation formats for commissioned equipment and assemblies, as assigned in the Check and Check and Testing Responsibility Table provided as a Supplement to this Section. Test procedures will include active testing, energy management control system trending and may include stand-alone data-logger monitoring.

1) Existing written testing requirements and procedures in accepted or required standards, guidelines or Specifications will suffice as the test procedures for the following: Regulated tests such as fire alarm, fire suppression, elevators, NETA electrical equipment tests, test procedures within these specifications and common Trade Subcontractor tests such as duct and piping tests.

r. Coordinate and assist in development of test plans, execution and documentation of tests of commissioned equipment overseen by regulatory authorities and ensure that such tests meet the testing and documentation rigor desired by the University. The systems for which this applies are indicated in the Check and Testing Responsibility Table in the supplements to this Section. Testing and commissioning for these systems shall be per the requirements of those Sections of the Specifications and the governing codes and standards. The Commissioning Authority shall work with the CMGC and Trade Subcontractors and University to ensure that these tests are scheduled and coordinated with the interfaces to other systems on the Project as well as requirements of the authorities having jurisdiction. Coordination efforts shall include but not be limited to:

1) Developing a logical test plan that flows from the component level on the various systems to the integrated testing of the systems as they interact with each other.

2) Verification that all necessary documentation requirements are met for all parties including but not limited to the authorities having jurisdiction, the University and the insurance underwriter.

3) Promoting and being proactive in the process and ensuring that all involved parties communicate effectively across the inter-discipline boundaries as required for successful integrated testing of the systems.

s. Coordinate testing for all commissioned systems and assemblies. Witness and document active tests performed by the Trade Subcontractors for all commissioned systems and assemblies, except: a) some smaller equipment may be tested and documented by the Trade Subcontractors, at the Commissioning Authority's discretion, b) electrical equipment testing and regulated testing may be directed and documented

by the Trade Subcontractor with only spot witnessing and report review by the Commissioning Authority. Refer to the Check and Testing Responsibility Table provided as a supplement to this Section for more specific delineation. The testing shall include operating the system and components through each of the written sequences of operation, and other significant modes and sequences, including start-up, shutdown, unoccupied mode, manual mode, staging, miscellaneous alarms, power failure, security alarm when impacted and interlocks with other systems or equipment. Sensors and actuators shall be calibrated during construction check listing by the installing Trade Subcontractors, and spot-checked by the commissioning provider during testing. Analyze functional performance trend logs and monitoring data to verify performance. Coordinate retesting as necessary until satisfactory performance is achieved.

t. After active testing and initial trouble shooting is complete, monitor system operation and performance for selected data points for up to 2 weeks by requesting trend logs from the Trade Subcontractor from the building automation system. Analyze monitored data to verify operation and performance and issue a written report.

u. Maintain a master Issues Log and a separate record of testing. Report all issues as they occur directly to the University. Provide directly to the University written progress reports and test results with recommended actions.

v. Review equipment warranties to ensure that the University responsibilities are clearly defined.

w. Oversee and approve the training of the University's operating personnel.

x. Review and approve the preparation of the O&M manuals for commissioned equipment.

y. Compile a Commissioning Record.

z. Compile a Systems Manual according to the definition and description in this Section for all commissioned systems.

2. HVAC and Mechanical-Specific Tasks of the Commissioning Authority

a. Controls Integration Meetings: Coordinate the approval process for the control system database and programming (point names, alarm limits, access levels, graphic details and layout, specific control strategies and sequences, etc.) via a series of meetings attended by the Trade Subcontractor, University, and Mechanical Engineer. The meetings shall occur after the software and data base drawings are issued for initial review, but prior to the development of the database and code for any piece of equipment.

b. Witness HVAC piping pressure test and flushing, sufficient to be confident that proper procedures were followed. Include documentation of all testing in the Commissioning Record.

c. Witness any ductwork testing and cleaning sufficient to be confident that proper procedures were followed. Include documentation of all testing in the Commissioning Record.

d. Approve air and water systems balancing by selected site observation, by reviewing completed reports and by spot testing.

e. Coordinate and approve the start-up of permanent equipment for temporary space conditioning during construction and review the plans for the use of temporary space conditioning equipment.

3. Process Systems Commissioning:

a. Refer to Division 01, Section 013513.13, Cleanroom Certification and Acceptance, for specific requirements.

4. Electrical System Specific Tasks of the Commissioning Authority: See Division 26, Section 260800, Commissioning of Electrical Systems, for Electrical System Requirements.

5. Static LEED Systems:

a. Refer to the Static elements commissioning article later in this Section.

6. Warranty Period:

a. Coordinate and supervise required opposite season or deferred testing and deficiency corrections and provide the final testing and sequence of operation update documentation for the Commissioning Record and O&M manuals.

b. Return to the site approximately 10 months into the 12 month warranty period and review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have with operating the

building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify deficiencies that may come under warranty or under the original construction contract. Assist facility staff in developing reports and documents and requests for services to remedy outstanding problems.

D. University:

1. Construction Phase:

a. Furnish a copy of all Construction Documents, addenda, requests for information, change orders and approved submittals and Shop Drawings related to commissioned equipment to the Commissioning Authority for their permanent retention.

b. Facilitate the coordination of the commissioning work by the Commissioning Authority.

c. With the CMGC and Commissioning Authority, ensure that commissioning activities are being scheduled into the master schedule.

d. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions according to the Commissioning Plan.

e. Participate in issue resolution as necessary.

f. Provide final approval for the completion of the commissioning work.

2. Warranty Period: Ensure that any seasonal or deferred testing and any deficiency issues are addressed.

E. General Contractor (GC)/CMGC

1. The GC/CMGC is fully responsible to the University for all Trade Subcontractor and CMGC listed responsibilities in the specifications. Separate responsibility listings are given in this Section for clarity purposes.

2. Construction Phase.

a. It is a requirement that the General Contractor (GC) /CMGC shall provide / designate a Commissioning Coordinator to organize, schedule, coordinate and direct the execution of the GC/CMGC's and Trade Subcontractor's commissioning responsibilities. The Commissioning Coordinator shall have experience in project management, scheduling and in the technical aspects of mechanical and electrical systems including commissioning of applicable equipment and systems. The General Contractor will submit resume(s) with applicable experience and references of their potential/selected Commissioning Coordinator. The General Contractor will be responsible for the selection of and or replacement of their designated Commissioning Coordinator at the GC’s expense should their Commissioning Coordinator not demonstrate acceptable performance throughout the contracted project at the discretion of the GC and or University. If the General Contractor refuses to provide for a Commissioning Coordinator, the University shall provide for that requirement at the General Contractor’s expense.

b. With the Commissioning Authority ensure that commissioning activities are being scheduled into the master schedule. The General Contractor and or their designated Commissioning Coordinator will provide a detailed schedule within the Master Construction Schedule that includes all systems, required tasks/activities inclusive of necessary permits, work tasks, safety compliance steps, etc by the mid-point of construction to the University and the Commissioning Authority.

c. Include Trade Subcontractor’s cost associated with commissioning in the total contract price.

d. Furnish a copy of all submittals and Shop Drawings related to commissioned equipment to the Commissioning Authority for their permanent retention during the normal submittal review cycle.

e. In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks and training that will meet the requirements of the Specifications.

f. Notify the Commissioning Authority when the installation will begin for static assemblies that are being commissioned, dates for pipe and duct system testing, flushing, cleaning, start-up of each piece of equipment and starting of testing adjusting and balancing. Notify the Commissioning Authority ahead of time, when commissioning activities not yet performed or not yet scheduled may delay construction.

g. Write and distribute construction checklists for equipment to be commissioned as assigned in this Section.

h. Provide time in selected construction meetings to cover commissioning-related issues.

3. Warranty Period.

a. Schedule and coordinate the Trade Subcontractors in correcting outstanding commissioning tasks and deficiencies.

F. GC/CMGC and Trade Subcontractors:

1. The details of this article apply to both the CMGC and sub-tier Subcontractors providing commissioned equipment. Other responsibilities for each party are listed in individual articles specific to each party.

2. Construction Phase.

a. Coordinate with the Commissioning Authority to facilitate the commissioning work.

b. Be proactive in seeing that commissioning processes are executed and that the requirements of the Commissioning Authority for the commissioning work are coordinated into the over-all construction schedule.

c. Attend the commissioning planning and kick-off meetings and other necessary meetings scheduled by the Commissioning Authority to facilitate the commissioning process.

d. Participate in the controls integration meetings coordinated by the Commissioning Authority, prior to submitting the controls submittal.

e. With the Architect and Commissioning Authority, actively assist in the development of the emergency power and fire alarm response matrix during the initial submittal period.

f. The CMGC and Trade Subcontractors shall respond to notices of issues identified during the commissioning process, making required corrections or clarifications and returning prompt notification to the Commissioning Authority.

g. When completion of a task or other issue has been identified as holding up any commissioning process, particularly functional testing, the Trade Subcontractor shall notify the CMGC within one day of identification. The CMGC shall within two days of notification of the issue, notify the Commissioning Authority and provide an expected date of completion or resolution of the issue. The CMGC shall notify the Commissioning Authority within one day of completion. It is not the responsibility of the Commissioning Authority to obtain this status information through meeting attendance, asking questions or field observation.

G. Trade Subcontractors:

1. Construction Phase:

a. In addition to the other responsibilities for the Trade Subcontractors listed in this Section, provide additional requested documentation, prior to normal O&M manual submittals, to the Commissioning Authority for development of functional and performance testing procedures.

b. Typically this will include detailed manufacturer installation, start-up, operating, troubleshooting and maintenance procedures, full details of any University-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the University to keep the warranty in force clearly identified. In addition, the installation, start-up and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Authority.

c. The Trade Subcontractor shall provide the Commissioning Authority, GC and Commissioning Coordinator additional documentation necessary for the commissioning process, when requested. This will include prior to the commissioning phase, a complete list of all equipment and/or materials necessary in completing the construction phase and or installation of all equipment and systems, noting what inventory is on site, installed, and what may need to be ordered, and received to complete construction. Any outstanding items that may need to be expedited will be done by the respective sub-contractor under the General Contractor's responsibility and expense in order to stay within the construction schedule.

d. Assist in clarifying the operation and control of commissioned equipment or assemblies in areas where the Specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.

e. Submit a written plan to the University and Commissioning Authority for temporary startup of equipment used for space conditioning. Obtain plan approval of University and Commissioning Authority prior to such startup.

f. Notify the GC/CMGC and or their Commissioning Coordinator when the installation will begin for static assemblies that are being commissioned, dates for pipe and duct system testing, flushing, cleaning, start-up of each piece of equipment and starting of testing adjusting and balancing. Provide significant advance

notification to the GC/ CMGC and or their Commissioning Coordinator ahead of time and prior to commissioning/project meetings, when commissioning activities not yet performed or not yet scheduled may delay construction. Also provide solutions to resolve the delay prior to and or with the notification.

g. During the installation, start-up and initial checkout process, document the execution of installation, start-up and initial checkout with parties having direct knowledge of each item being checked off and provide a copy to the Commissioning Authority.

h. During construction, maintain red-line documents for Trade Subcontractors-generated coordination drawings. Update after completion of commissioning (excluding deferred seasonal testing).

i. Record daily all issues that arise during the testing, adjusting and balancing work, such as damaged or missing duct or insulation, sensors, wiring, valves, dampers, controls, programming, equipment, components, etc. or items that will reduce the effectiveness of the installation or prevent accurate air and water balancing or systems or building control. During balancing, provide the Commissioning Authority this list of issues once a week within 1 day of the end of the reported week.

j. Review test procedures developed by the Commissioning Authority to ensure feasibility, safety and equipment protection and provide necessary alarm limits to be used during the tests.

k. Develop test plans with review and approval of the Commissioning Authority per the Check and Testing Responsibility Table provided as a supplement to this Section.

l. Write step-by-step test procedures and documentation formats for commissioned equipment and assemblies, as assigned in the Check and Testing Responsibility Table provided as a Supplement to this Section. Test procedures will include active testing, energy management control system trending and may include stand-alone data-logger monitoring.

m. Existing written testing requirements and procedures in accepted or required standards, guidelines or Specifications will suffice as the test procedures for the following: Regulated tests such as fire alarm, fire suppression, elevators, NETA electrical equipment tests, test procedures within these specifications and common industry tests such as duct and piping tests.

n. Execute testing for selected systems and assemblies under the direction of the GC and or their Commissioning Coordinator in accordance with, and documented by the Commissioning Authority as listed in the Check and Testing Responsibility Table. Direct, execute, and document testing on selected systems as listed in the Check and Testing Responsibility Table provided as a supplement to this Section.

o. Assist and cooperate with the Commissioning Authority by putting all commissioned equipment and systems into operation and continuing the operation during each working day of testing, as required.

p. Remedy outstanding Architect “punch list” items that may affect equipment operation before testing. Air and water testing adjusting and balancing shall be completed with discrepancies and problems remedied before testing of the respective air- or water-related systems.

q. Provide all tools or the use of tools to start, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the Commissioning Authority.

r. Provide skilled technicians and perform testing under the direction of the Commissioning Authority for equipment and assemblies specified for testing in this Section. In particular, the person tasked with operating the controls system during testing shall be familiar with this building and control program. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete necessary tests, adjustments and problem-solving. For larger mechanical equipment, provide the services of the start-up technician for the beginning of the testing of the equipment.

s. Ensure that the local authorities having jurisdiction are available to witness any acceptance test (e.g., fire alarm testing, smoke cycle testing, fire damper acceptance testing, sprinkler system hydro-testing, etc.) that is a condition of occupancy for the building.

t. Provide assistance to the Commissioning Authority in interpreting apparent system performance problems from monitored and test data.

u. Respond in writing to each issue. Correct deficiencies (differences between specified and observed performance) as interpreted by the Commissioning Authority, University and Architect and retest the equipment.

v. Train University personnel using expert qualified personnel according to the Contract Documents.

w. Prepare O&M manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions, and submit a copy to the Commissioning Authority for review.

x. Provide necessary documentation for the Systems Manual as described in this Section.

y. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty during occupancy. Provide this information to the University.

z. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty during occupancy. Provide this information to the University.

aa. Designate the Contractor's mechanical, electrical, plumbing (MEP) superintendent and/or employ a professional Commissioning Authority/Agent to act as the Commissioning Coordinator for the Contractor with the following responsibilities. The Commissioning Coordinator may have other project responsibilities, but the priority will be:

1) Direct, organize, schedule and coordinate the commissioning activities for the Contractor and facilitate systems being installed, started up and checked out in sequence to accommodate all testing /commissioning in accordance with the Commissioning Authority.

2) Beginning at least 60 days prior to starting up the first major piece of HVAC equipment, generate and manage a Construction Completion Issues Log that tracks issues of commissioned systems that are late, holding up the critical path, are long lead items, need special coordination or are somewhat contested. This is not the same as the Commissioning Authority's Commissioning Issues Log which focuses on deficiencies identified during inspection and testing.

3) Attend all commissioning meetings.

4) Direct the timely resolution and correction of issues that arise during the commissioning process.

5) Track and encourage progress on the filling out of the construction checklists by trade subcontractors.

6) Monitor progress of the balancing contractor and ensure they are following the specifications and balancing plan.

7) Prior to functional testing, ensure that trade subcontractors have completed a thorough checkout of their systems, have reviewed the functional test procedures and have confirmed the equipment and system is ready for functional testing.

8) Work with the Commissioning Authority in creating and managing the functional testing schedule.

9) Maintain a set of the sequences of operation and control drawings that have all updates, changes and clarifications redlined.

10) Prior to their generation, review the Contractor's format and content plan for the O&M manuals to ensure it is consistent with the specifications.

11) Prior to training, review the Contractor's format and content plan for operator training to ensure it is consistent with the specifications. Track status for completion of all training provided by the Subcontractor(s) in accordance with the with the contract specifications.

12) Provide coordination, directing, documentation, witnessing, etc. of functional tests as shown on the Check and Testing Responsibility Table.

13) During Warranty Period:

a) Coordinate seasonal or deferred testing, witnessed by the Commissioning Authority, according to the Specifications.

b) Correct deficiencies and make necessary adjustments to O&M manuals and Record Documents for applicable issues identified in any seasonal or warranty period testing.

2. Warranty Period:

a. Correct deficiencies and make necessary adjustments to O&M manuals and red-line documents for applicable issues identified in any seasonal or warranty period testing.

H. Equipment Suppliers:

1. Construction Phase:

a. Provide requested submittal data, including detailed start-up and checkout procedures and specific

responsibilities of the University to keep warranties in force for all commissioned equipment or assemblies.

b. Assist in equipment or assembly testing per agreements with Trade Subcontractors.

c. Include all special tools and instruments, when only available from vendor, specific to a piece of equipment, required for testing equipment according to these Contract Documents in the base bid price to the CMGC or Trade Subcontractors.

d. University to provide information requested by Commissioning Authority regarding equipment sequence of operation and testing procedures.

e. Review test procedures for equipment installed by factory representatives.

f. For larger primary equipment, provide the services for the first part of testing, of the technician that conducted start-up. For electrical commissioning, see Table of Testing Responsibility provided as a supplement to this Section.

g. Provide expert qualified staff for equipment training.

1.4. SUBMITTALS

A. The CMGC and Trade Subcontractors shall provide the Commissioning Authority with information required to facilitate the commissioning process from written requests.

B. Standard Equipment and Assembly Submittals.

1. Prior to standard equipment and assembly submittals being issued, the CMGC shall provide the Commissioning Authority with a submittal register. The Commissioning Authority will check which submittals they desire to review and comment on and which they need only copies of the approved submittals.

2. The submittals reviewed may be done in parallel with A/E reviews or in series with them, depending on protocol set by the University.

3. The reviews will consist of commenting relative to conformance to the Contract Documents as it relates to the commissioning process, to the functional performance of the equipment, adequacy for developing test procedures and for O&M issues. The reviews are intended primarily to aid in the development of testing procedures and only secondarily to verify compliance with equipment Specifications.

C. Other Equipment and Assembly Information.

1. When not included with the standard submittals, the Trade Subcontractors shall provide to the Commissioning Authority requested shop drawings, the manufacturer's printed installation and detailed start-up procedures, full sequences of operation, O&M data, performance data, any performance test procedures, control drawings and details of University contracted tests. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Authority. This documentation will be required prior to the normal O&M manual submittals.

D. All equipment and assembly documentation requested by the Commissioning Authority shall be included by the Trade Subcontractors later in the O&M manuals.

E. The Trade Subcontractors shall submit all company and required staff qualifications.

F. The Trade Subcontractors shall submit checklists and startup and test plans, forms and procedures as indicated on the Check and Testing Responsibility Table.

G. The Trade Subcontractors and Architect shall provide additional design narrative information requested by the Commissioning Authority, depending on the completeness of the Design Record documentation and sequences provided with the Specifications.

1.5. QUALITY ASSURANCE

A. Test Equipment:

1. All standard testing equipment required for the Trade Subcontractors to perform installation, start-up and initial checkout and required testing shall be provided by the Trade Subcontractors.

2. Special tools and instruments, only available from vendor, specific to a piece of equipment, required for testing equipment according to these Contract Documents shall be included in the base bid price.

3. The Trade Subcontractors shall provide datalogging equipment for setting up and testing of cold rooms, clean

room certification, fume hoods and lab room pressurization, and equipment required to perform specified electrical equipment testing.

4. Datalogging equipment required for testing equipment in support areas shall be provided and used by the Commissioning Authority.

B. Test Equipment Calibration Verification:

1. Trade Subcontractors shall submit, within 90 days of notice to proceed and 30 days before any testing is performed, documentation of meeting the following calibration requirements.

2. Electrical equipment testing instruments must be calibrated in accordance with the following frequency:

a. Field Instruments: Analog, 6 months maximum, digital, 12 months maximum.

b. Laboratory Instruments: 12 months.

c. Leased specialty equipment: 12 months where accuracy is guaranteed by lessor.

3. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the Specifications.

a. If not otherwise given, the following minimum requirements apply: Temperature sensors and digital thermometers shall have a certified calibration within the past year to an accuracy of 0.5 degrees F and a resolution of + or - 0.1 degrees F. Pressure sensors shall have an accuracy of + or - 2.0 percent of the value range being measured (not full range of meter) and have been calibrated within the last year. All equipment shall be calibrated according to the manufacturer's recommended intervals and when dropped or damaged. Calibration tags shall be affixed or certificates readily available.

1.6. COORDINATION

A. Commissioning Team: The members of the commissioning team consist of the Commissioning Authority, the University, the CMGC, the Architect and design engineers, the mechanical contractor, the electrical contractor, the testing adjusting and balancing contractor, the controls contractor, any other installing subcontractors or suppliers of commissioned equipment or assemblies and the University's building or plant operator/Engineer.

B. Management: The Commissioning Authority is hired by the University directly. The Commissioning Authority directs and coordinates the commissioning activities and reports to the University. All members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents.

C. Scheduling: The CMGC shall provide sufficient notice to the Commissioning Authority regarding the installation of static assemblies being commissioned and the schedule for the construction checklists, start-up and initial checkout of all commissioned dynamic equipment and systems. Refer to Schedule under Part 3, EXECUTION, for additional scheduling details.

D. Meetings: Refer to Part 3, EXECUTION, for a description of meetings required as part of the commissioning process.

E. General: The CMGC and the Trade Subcontractors will coordinate with the Commissioning Authority in a number of areas as described in this Section in order to facilitate the successful completion of the commissioning plan.

PART 2 - PRODUCTS NOT USED

PART 3 - EXECUTION

3.1. MEETINGS

A. Planning Meeting: Within 30 days of commencement of construction, the Commissioning Authority will schedule, plan and conduct a commissioning planning meeting with the Architect, and mechanical and electrical engineering subconsultants, the CMGC, University and facility operator or representative. During this meeting, the overall scope and process of the commissioning effort for this Project will be described, issues and suggestions from all parties given, management and reporting protocols finalized and the Project schedule discussed. From information gathered in this meeting, the Commissioning Authority will update the Commissioning Plan preparatory to the commissioning kick-off meeting. Meeting minutes will be distributed to all parties by the Commissioning Authority.

B. Kick-off Meeting: Within 30 days from the planning meeting, the Commissioning Authority will schedule, plan and conduct a commissioning kick-off meeting with the entire commissioning team in attendance, including the controls, sheet metal, electrical, mechanical, test, adjusting and balancing and other appropriate Trade Subcontractors and the facility operator or representative in attendance. One week prior to this meeting, the updated commissioning plan will be distributed to all members for their review. The commissioning plan, the overall commissioning process and general responsibilities of each team member, reporting and communication protocols and next steps will be

discussed. Meeting minutes will be distributed to all parties by the Commissioning Authority.

C. Temporary or Early Startup of Equipment. When equipment will be used in a temporary mode prior to operating the equipment permanently, a meeting shall be held that discusses the issues surrounding indoor environmental quality, moisture intrusion, building pressurization, duct and equipment cleanliness, checkout of safeties and fire alarm and protection, etc.

D. Miscellaneous Meetings: Deficiencies in compliance with the contract documents identified through the commissioning process or other means shall be discussed, as needed, in portions of regular construction meetings. Meetings dedicated to deficiencies or commissioning: status, coordination and planning shall also be conducted. The Commissioning Authority will plan, conduct and take minutes at commissioning meetings. When practical, commissioning meetings will be an appendage to regular construction meetings. All commissioning meetings shall be attended by the CMGC, the mechanical and the controls subcontractors. Selected meetings shall require the attendance of the electrical, sheetmetal, fire alarm, TAB or other trades of commissioned systems or assemblies. The number of specific meetings dedicated to commissioning, besides those specifically listed in this Section are expected to consist of:

1. From 30 days prior to setting ductwork or mechanical equipment until the startup of the first piece of major mechanical equipment: 1 hour meetings every 6 weeks.
2. From the startup of the first piece of major mechanical equipment until the beginning of functional testing of mechanical equipment: 1 hour meetings every two weeks.
3. From the beginning of functional testing of mechanical equipment until all mechanical equipment has had the first round of testing conducted: 1 hour meetings once a week.
4. From the end of the first round of testing until all deficiencies are corrected: 1 hour meetings once a week or as set by the University.
5. If the number of deficiencies is abnormal or coordination or cooperation is insufficient, additional meetings or meeting durations shall be required.

E. Controls Integration Meetings: The Commissioning Authority coordinates a series of meetings to go over the control drawings, sequences of operation, points list and database and controls submittal requirements. These meetings are held prior to a formal control drawing submittal and any programming. The intent is to clarify control related issues for the controls contractor, mechanical, fire alarm and electrical contractor, University facility staff and Commissioning Authority prior to final point database development, programming and the formal control drawing submittal.

1. The controls contractor shall attend all meetings. The mechanical, electrical and general contractor shall attend when issues regarding equipment they are responsible for are discussed. The mechanical and electrical designers attend as needed according to their contracts. The control technicians attending the meetings must be the same technicians that are/will install and program the DDC system.
2. Preliminary control drawing submittals and sequences by system are provided by the Controls Contractor, reviewed beforehand and discussed at these meetings.
3. Primary issues discussed and clarified are:
    a. Control drawing content and format
    b. Point database (points (monitored points, software points, naming conventions, alarms, report format)
    c. Sequences of operation and setpoints (clarity, completeness, design intent, functionality, and enhancements for control, energy and O&M)
    d. Interlocks to packaged controls and other systems, including filling in the fire alarm and emergency power response matrices
    e. Operator workstation graphics
    f. Field sensor and panel locations
4. A site walk-through with the Controls Contractor, Commissioning Authority and Engineer shall be conducted where precise locations of panels, sensors, thermometers, flow meters and stations and valve taps will be identified.
5. The Commissioning Authority takes minutes at these meetings, which may include marked up data base forms and sequences of operation.

3.2. CONSTRUCTION CHECKLISTS, START-UP, AND INITIAL CHECKOUT

A. The following procedures apply to all equipment and assemblies to be commissioned:

1. Static Elements: Systems or assemblies that are static in nature (not dynamic like mechanical or some electrical systems) may have very simplified construction checklists for installation and may have no start-up or testing requirements. Refer to the Static Elements article later in this Section for specific requirements.

2. Construction Checklists:

a. The CMGC develops new or adapts existing representative construction checklists and procedures for commissioned equipment and assemblies according to the notation in the list of commissioned systems in Part 1, GENERAL, of this Section. A representative checklist for mechanical systems is found as a supplement to this Section. Electrical equipment component check forms are considerably simpler than the mechanical example.

b. Calibrations: The construction checklists will contain requirements for calibrations when applicable. The Trade Subcontractors is responsible to calibrate all field-installed sensors and actuators using test and documentation methods approved by the Commissioning Authority.

c. On each Construction Checklist the CMGC shall identify which trade or contractor is responsible for executing and documenting each of the line item tasks and shall note that trade on the checklist form.

d. Checklists may be attached to test procedure forms.

3. Manufacturer Installation and Startup Procedures:

a. The Trade Subcontractors shall document their installation and startup utilizing manufacturer installation and startup procedures, check sheets and reports, in addition to the commissioning construction checklists.

b. The completed manufacturer startup reports shall be submitted to the Commissioning Authority within 5 days of startup. The Contractor shall clearly note any items that have not been completed and the plan for their completion.

4. Execution of Construction Checklists and Start-up:

a. Each piece of equipment shall receive full construction checkout by the Trade Subcontractors following the approved plan and forms. No sampling strategies are used. Only individuals that have direct knowledge and witnessed that a line item task on the construction checklist was actually performed shall initial or check that item off. It is not acceptable for non-witnessing supervisors to fill out the forms.

b. The Trade Subcontractors shall complete the pre-start procedures in the construction checklist prior to starting equipment, including but not limited to verification of completion of wiring, safeties, lubrication, drive rotation and proper electrical test readings. Startup shall be conducted under supervision of responsible manufacturer representatives for major pieces of equipment. The CMGC shall notify the Commissioning Authority at least 5 days in advance of any equipment start-up, providing the Commissioning Authority a copy of the pre-start sections of the installation and start-up plan at that time.

c. The Commissioning Authority shall observe installation, start-up and checkout of selected systems. Procedures on the plans and checklists will be spot-checked by the Commissioning Authority prior to testing.

d. The Trade Subcontractors and vendors shall execute start-up and provide the Commissioning Authority with a signed and dated copy of the completed construction checklists and installation and start-up documentation. The Trade Subcontractors shall clearly note any items that have not been completed and the plan for their completion.

e. The Trade Subcontractors shall operate each commissioned device or assembly to the full extent of its capability, from minimum to maximum, under automatic and manual control and verify that the equipment, system and assembly is functioning according to the specifications, manufacturer's recommendations and good operating practice.

f. The Construction Checklist and manufacturer installation and startup check sheets and procedures for a given system shall be successfully completed and submitted prior to formal testing or testing, adjusting, and balancing of the equipment.

g. Where final balancing of a system or particular components thereof are not specifically indicated to be performed by the University or University's consultants, the CMGC and Trade Subcontractors shall provide final balancing and adjustments for operation within specified tolerances prior to testing and demonstration of such system.

h. The Trade Subcontractors shall submit installation, startup and checkout documentation prior to testing

equipment.

i. The Commissioning Authority will review installation, startup and checkout documentation and identify incomplete areas.

j. The Trade Subcontractors shall correct all areas that are deficient or incomplete in the checklists in a timely manner.

3.3. PHASED START-UP AND TESTING – CLEAN ROOM

A. The Project will require start-up and initial checkout to be executed in phases. This phasing will be planned and scheduled in detail in coordination meetings. Results will be added to the master schedule.

1. The intent of this phasing is to ensure that sufficient chilled and heating water and electrical power (including backups) are confidently available to the systems serving the clean room during successively cleaner clean room stages, without requiring processes that will contaminate the clean room.

2. This will require that primary equipment (chillers, boilers, clean room air handlers, power and generator) will be started, partially balanced and functionally tested and put into active operation. Then, later as ancillary and secondary portions of the primary equipment are finished and tested, both primary and secondary systems shall be functionally tested as a complete system, with some primary system functions being tested twice.

B. Any equipment started up or tested which later is modified shall have affected portions or potentially affected portions of equipment, sequences and interlocks retested to ensure that the entire system or assembly functions properly.

3.4. TESTING

A. This sub-section applies to all commissioning testing for all Divisions of the Project Manual.

B. The Trade Subcontractors shall be responsible to fully test all systems and assemblies according to the Specifications. The Commissioning Authority will direct, witness and document most of the mechanical systems tests. The electrical Trade Subcontractors shall direct and document most electrical component tests with the Commissioning Authority spot witnessing and reviewing completed reports. The Trade Subcontractors shall execute all tests; except at the discretion of the Commissioning Authority, and approval of the Trade Subcontractors, the Commissioning Authority may execute tests of selected equipment. Refer to the Check and Testing Responsibility Table provided as a supplement to this Section for details.

C. Tests for a given system or assembly shall not be conducted until they are fully operational under normal and reliable control with control calibrations, programming and control system graphics complete and checked out and the Trade Subcontractors have submitted a completed construction checklist and where applicable a startup report, satisfactory to the Commissioning Authority.

D. Testing Requirements: The testing requirements for specific systems and assemblies are found in other specification sections.

E. Objectives and Scope:

1. The objective of testing is to demonstrate that each system is operating according to the documented University Objectives and Contract Documents. For dynamic systems, testing facilitates bringing the systems from a state of initial operation to full dynamic operation. For static elements, testing verifies the performance of the assembly in its installed state under conditions specified in the testing requirements. Additionally, during the testing process, areas of deficient performance are identified and corrected.

2. In general, testing shall include testing each sequence in the sequence of operations, and other significant modes, sequences and control strategies not mentioned in the written sequences; including, but not limited to startup, shutdown, unoccupied and manual modes, modulation up and down the unit's range of capacity, power failure, alarms, component staging and backup upon failure, interlocks with other equipment, and sensor and actuator calibrations. All interlocks and interactions between systems shall be tested. All larger equipment will be individually tested. Like units or assemblies that are numerous (many smaller rooftop packaged units, air terminal units, exhaust fans, windows, etc.) may have an appropriate sampling strategy applied. Heating equipment must be tested appropriately during winter and air conditioning equipment must be tested appropriately during summer to demonstrate performance under near-design conditions.

F. Development of Functional and Performance Test Procedures:

1. Test procedures and documentation forms are not finalized until after equipment and control system submittals and shop drawings are approved. The party responsible for developing, reviewing and approving the procedures is given in Supplement 3 to this Section.

2. The party responsible for writing the test procedures obtains needed documentation which generally includes equipment Specifications, testing requirements, O&M manuals, approved submittals and shop drawings, start-up instructions, sequences of operation, and mechanical, electrical and control drawings and writes detailed step-by-step testing procedures to comply with the testing requirements.
3. Prior to execution, any test procedures developed by the Commissioning Authority are provided to the Trade Subcontractors who shall review the tests for feasibility, safety, equipment and warranty protection.
4. Prior to execution, test forms developed by the Trade Subcontractors are reviewed and approved by the Commissioning Authority.
5. Test procedures shall be written and submitted to reviewers at least 14 days prior to executing the tests.

G. Test Procedure Format: Three sample test forms for mechanical equipment are provided in Supplement 2 to this Section. The final test procedure forms shall include (but not be limited to) the following information:

1. System and equipment or component name(s).
2. Equipment location and ID number.
3. Unique test ID number and reference to unique construction checklist and start-up documentation ID numbers for the piece of equipment.
4. Date.
5. Project name.
6. Participating parties.
7. A copy of the Specification Section describing the test requirements.
8. A copy of the specific sequence of operations or other specified parameters being verified.
9. Formulas used in any calculations.
10. Required pre-test field measurements.
11. Instructions for setting up the test.
12. Special cautions, alarm limits, etc.
13. Specific step-by-step procedures to execute the test for each sequence or feature being verified, in a clear, sequential and repeatable format. Each must be tailored and applicable to this project.
14. Acceptance criteria of proper performance with a “Yes/No” check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
15. A section for comments.
16. Signatures and date block for the Commissioning Authority.

H. The Commissioning Authority will review University-contracted, factory testing, required University-witnessed acceptance tests and tests conducted by regulatory authorities which the Commissioning Authority is not responsible to oversee, including documentation format, and will determine what further testing or format changes may be required to comply with the Specifications and rigor desired by the University. Redundancy of testing shall be minimized. Documentation of these tests will be included in the Commissioning Record.

I. Test and Verification Methods:

1. Testing and verification for most dynamic equipment shall be achieved by an appropriate combination of active testing (persons manipulate the equipment and observe its function) or by monitoring the performance and analyzing the results using the control system’s trend log capabilities or by stand-alone dataloggers. For certain tests documenting with photographs, video or audio recordings may be appropriate. The testing requirements sections of the Specification describe which methods shall be used for each test. The Commissioning Authority may substitute specified methods or require an additional method to be executed, other than what was specified, with the approval of the University.
2. Simulated Conditions: Simulating conditions other than by overwriting a value shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
3. Overwritten Values: Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used

with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other systems will be erroneous or not applicable. Simulating a condition is preferable, e.g., for the above case, by heating the outside air sensor with a hair blower rather than overwriting the value or by altering the appropriate setpoint to see the desired response. Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.

4. Simulated Signals: Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.

5. Altering Setpoints: Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55 degrees F, when the outside air temperature is above 55 degrees F, temporarily change the lockout setpoint to be 2 degrees F above the current outside air temperature.

6. Indirect Indicators: Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual conditions and responses. Much of this verification is completed during construction checklists and calibrations.

7. Setup: Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Trade Subcontractors shall provide all necessary materials, system modifications, etc., to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the Trade Subcontractors shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.

8. Sampling: Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy. Significant application differences and significant sequence of operation differences in otherwise identical equipment invalidates their common identity. A small size or capacity difference, alone, does not constitute a difference. The specific recommended sampling rates are specified with the testing requirements. It is noted that no sampling by the Trade Subcontractors is allowed in construction checklist execution.

9. Testing Order: In general, testing is conducted after construction checklisting and start-up has been satisfactorily completed. The control system is sufficiently tested and approved by the Commissioning Authority before it is used for testing, adjusting and balancing or to verify performance of other components or systems. The air balancing and water balancing is completed and debugged before testing of air-related or water-related equipment or systems. Testing generally proceeds from components to sub-systems to systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is verified.

10. Trend Logs and Monitoring: Trend logs required in the testing requirements shall be set up and executed by the Trade Subcontractors and provided to and analyzed by the Commissioning Authority. Monitoring using dataloggers will be conducted by the Commissioning Authority. Trend logs and monitoring are conducted after active testing and subsequent trouble-shooting are complete and systems are in normal operation without frequent service shutdowns, etc.

J. Problem Solving: The burden of problem solving is on the CMGC and Trade Subcontractors and the Architect, though the Commissioning Authority may recommend solutions to problems found.

3.5. ISSUES AND NON-CONFORMANCE

A. Issue Management

1. The Commissioning Authority will record the results of document reviews, field observations, tests conducted or reviewed and trend logs or monitoring. All deficiencies or non-conformance issues will be recorded on a master Issues Log kept by the Commissioning Authority. The Issues Log will be kept updated by the Commissioning Authority.

2. A current copy of the Issues Log will be provided to the CMGC and University on a regular basis, as requested by the CMGC or University. New issues since the last printing will be explicitly identified.

3. Issues warranting a request for information (RFI) will be forwarded by the Commissioning Authority to the designated party for developing the RFI, or the Commissioning Authority will generate and forward the RFI directly.

4. Issues of non-compliance or items that are incomplete or are requiring Designer input will be sent to the CMGC

or Designer and University by the Commissioning Authority via appropriate channels.

5. For some issues it may be unclear whether the issue requires a Designer response prior to action. The Commissioning Authority will in those cases send the issue to either the Designer or to the CMGC or possibly both. If the Designer or CMGC believe it is not their initial responsibility, they shall state this in a reply to the Commissioning Authority within two days of receipt. The Commissioning Authority will forward to the designated party.
6. The Issue Memorandum sent via email to the CMGC or Designer on each issue will include a statement whether the resolution of the issue is holding up or will likely delay a commissioning process and a deadline for a response. Responses can be made by replying to the original email.
7. When completion of a task or other issue has been identified by the Commissioning Authority as holding up or is likely to delay any commissioning process, particularly functional testing, the CMGC or Designer, as applicable, shall be required (as noted in the Issue Memorandum), within two days of notification of the issue, to notify the Commissioning Authority in writing providing the planned actions and an expected date of completion. The CMGC shall notify the Commissioning Authority in writing within one day of completion listing the actions taken to resolve the issue. It is not the responsibility of the Commissioning Authority to obtain this status information through meeting attendance, asking questions or field observation.
8. The Commissioning Authority documents resolutions in the Issues Log and schedules retesting and reinspection as needed.
9. Corrections of minor issues identified may be made during the tests at the discretion of the Commissioning Authority and with the issue and resolution documented in the Issues Log.
10. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the Commissioning Authority will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues, unless there is an overriding reason to do so at the written request of the University.
    a. Cost of Retesting: Problems identified during testing will fall into the following five categories.
        1) Equipment or hardware not installed or not installed properly.
        2) Controls program not per the approved sequence of operation (either the specific specified sequence was not programmed, or the methods and subroutines used to meet the specified sequence or performance requirement do not meet the objectives).
        3) Air or water balancing does not meet the design documents when the system has the capacity to do so.
        4) Specified design control sequences, setpoints or schedules require modification to achieve proper operation or control.
        5) Design balancing quantities require modification.
    b. If a delay occurs because of the case of (1), (2) or (3) in the article immediately above, no additional compensation will be given to the subcontractor involved in troubleshooting, making corrections or retesting.
    c. If a delay occurs because of the case of either (4) or (5) in the article above, additional compensation may be required depending on how quickly revisions can be made.
    d. The determination of the cause of the problem will be by agreement between the University, the Architect and design subconsultants, the Commissioning Authority and the CMGC.
    e. For a deficiency identified, not related to any construction checklist or start-up omission or fault, the following shall apply: The Commissioning Authority will direct, document and evaluate the retesting of up to 10% of the test procedures of the equipment once at no “charge” to the Trade Subcontractor or CMGC for their time. However, the Commissioning Authority’s time for additional retesting beyond 10% will be charged to the CMGC.
    f. The time for the Commissioning Authority to direct, document and evaluate any retesting required because a specific construction checklist or start-up test item, reported to have been successfully completed, but determined during testing to be faulty, will be charged to the CMGC.
    g. The CMGC shall reimburse the University and Commissioning Authority for costs when a scheduled test cannot be completed due to:
        1) Failure of the CMGC to schedule the test with all parties required to perform the test or with regulatory authorities required to witness the test.

2) Failure of the CMGC to provide required notice for tests that have been cancelled or rescheduled.

3) Failure of the CMGC or Trade Subcontractors to have in place test equipment, support equipment, instrumentation, permits, or other ancillary equipment or systems required for successful execution of the test.

4) Failure of the Trade Subcontractors to complete pre-start or start-up procedures or other work required as a prerequisite for execution of the test.

11. The CMGC shall respond in writing to the Commissioning Authority and University at least as often as commissioning meetings are being scheduled concerning the status of each outstanding issue identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.

12. Any required retesting by the Trade Subcontractors shall not be considered a justified reason for a claim of delay or time extension by the Trade Subcontractors.

B. Failure Due to Manufacturer Defect: For identical or near-identical components numbering more than 10 (e.g., terminal units, diffusers, traps, valves, etc.). If in the opinion of the University or Designer, 10 percent, or 3, whichever is greater, of identical pieces (size alone does not constitute a difference) of equipment fail to perform to the Contract Documents (mechanically or substantively) due to manufacturing defect, not allowing it to meet its submitted performance Specification, all identical units may be considered unacceptable by the University. In such case, the Trade Subcontractors shall provide the University with the following:

1. Within 1 week of notification from the University, the Trade Subcontractors or manufacturer's representative shall examine all other identical units making a record of the findings. The findings shall be provided to the University within 2 weeks of the original notice.

2. Within 2 weeks of the original notification, the Trade Subcontractors or manufacturer shall provide a signed and dated, written explanation of the problem, cause of failures, etc., and all proposed solutions which shall include full equipment submittals. The proposed solutions shall not significantly exceed the Specification requirements of the original installation.

3. The University will determine whether a replacement of all identical units or a repair is acceptable.

4. Two examples of the proposed solution will be installed by the Trade Subcontractors and the University will be allowed to test the installations for up to 1 week, upon which the University will decide whether to accept the solution.

5. Upon acceptance, the Trade Subcontractors and/or manufacturer shall replace or repair all identical items, at their expense and extend the warranty accordingly, if the original equipment warranty had begun. The replacement/repair work shall proceed with reasonable speed beginning within 1 week from when parts can be obtained.

C. Approval and Acceptance: The Commissioning Authority will note each satisfactorily demonstrated function on the test form. However, formal approval of an entire test form is not normally given. Functional approval or acceptance of a system is indicated after all testing and monitoring is complete and there are no outstanding issues for that equipment or assembly in the Commissioning Authority's Issues Log.

3.6. DEFERRED TESTING

A. Unforeseen Deferred Tests: If any check or test cannot be completed due to the building structure, required occupancy condition or other deficiency, execution of checklists and testing may be delayed upon written approval of the University.

B. Seasonal Testing: During the warranty period, seasonal testing (tests delayed until weather conditions are closer to the system's design) specified in the testing requirements shall be completed as part of this contract. The Commissioning Authority will coordinate this activity. Tests will be executed, documented and deficiencies corrected by the Trade Subcontractors, with facilities staff and the Commissioning Authority witnessing. The Trade Subcontractors shall make needed final adjustments to the O&M manuals and Record Documents due to the testing results.

3.7. DOCUMENTATION

A. Commissioning Plan: The Commissioning Plan is defined in this Section and follows the process outlined in the Specifications. The Commissioning Authority will develop and update the commissioning plan as construction progresses. The Specifications will take precedence over the Commissioning Plan.

B. Schedule: The University and CMGC and the Trade Subcontractors shall work with the Commissioning Authority using established protocols to schedule the commissioning activities. The University and CMGC shall integrate all

commissioning activities into the master schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process. As construction progresses, more detailed commissioning schedules shall be developed. The CMGC shall provide a minimum of 2 weeks notice prior to the date of testing to the University and Commissioning Authority. In addition, the Commissioning Authority and University shall be notified 36 hours in advance when tests are canceled or rescheduled.

C. Documentation required of the Trade Subcontractors shall consist of the following:

1. Construction checklist form completed.
2. Startup and initial checkout forms completed.
3. Completed test forms and record of deficiencies and incomplete items for tests they are responsible to document.
4. Training record (see Division 01, Section 017900, Demonstration and Training).
5. Contributions to Systems Manual (flow diagrams, fire alarm and emergency power matrix, seasonal startup and shutdown procedures, red-line drawings).

D. Reporting and Documentation by the Commissioning Authority:

1. The Commissioning Authority will provide regular reports of all issues and progress directly to the University with increasing frequency as construction and commissioning progresses. Issues that are in the schedule critical path or which significantly affect budget or building performance will be reported within 2 days of identification.
2. The Commissioning Authority will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling changes through memos, progress reports, etc.
3. The Commissioning Authority will witness and document the results of all functional and performance tests using the specific procedural forms developed for that purpose. The Commissioning Authority will include the filled out forms in the Commissioning Record.
4. Systems Manual: A Systems Manual will be compiled by the Commissioning Authority. See details in this Section.
5. Commissioning Record: The Commissioning Authority is responsible to compile, organize and index commissioning data by equipment and assembly into labeled, indexed and tabbed, three-ring binders and deliver it to the University, to be included with the O&M manuals. Three copies of the manuals will be provided. The record will contain for all systems and assemblies together the Summary Report, Issues Log, Commissioning Plan, progress reports, submittal reviews, O&M manual reviews, summary training record, Design Record, testing schedule. Then for each system or assembly the sequence of operation, construction checklist, start-up report, test record, training record, and the indexed and fully labeled trend log analysis of all systems. Included in the record will be all outstanding non-compliance items specifically listed. Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc. shall also be listed. Each non-compliance issue shall be referenced to the specific test, inspection, trend log, etc. where the deficiency is documented.
6. Summary Report: The summary commissioning report will include an executive summary, list of participants and roles, brief building description, overview of commissioning and testing scope and a general description of testing and verification methods. For each piece of commissioned equipment or assembly, the report will contain the disposition of the Commissioning Authority regarding the adequacy of the equipment, documentation and training meeting the Contract Documents in the following areas: 1) installation, including equipment meeting the equipment Specifications, 2) functional performance and efficiency, 3) equipment O&M manual documentation, and 4) operator training. All outstanding non-compliance items shall be specifically listed. Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc. will also be listed. Each non-compliance issue will be referenced to the specific test, inspection, trend log, etc. where the deficiency is documented. The functional performance and efficiency section for each piece of equipment will include a brief description of the verification method used (active testing, FMCS trend logs, data loggers, etc.) and include observations and conclusions from the testing.

E. Systems Manual: The Commissioning Authority (CA) will compile a Systems Manual. The following components of the manual are organized and indexed by system into one compilation. The responsibility of the Trade Subcontractors and other parties in the System Manual development are given in brackets.

1. Design Record: The Design Record for each system or assembly included in the Systems Manual, consists of:
   a. University Requirements and Objectives (see Definitions). [By Architect.]

b. Design Basis (see Definitions). [By Architect.]

c. Design Narrative (see Definitions). [By Architect.]

d. Performance Metrics/Benchmarks, if developed (see Definitions). [By CA, if in scope.]

2. Fire and life safety and emergency power criteria including a general strategy narrative, detailed sequences and an HVAC fire and emergency power response matrix. [Format by CA and content by Trade Subcontractors and Architect.]

3. Flow Diagrams: Include reductions of the flow or one-line diagrams from the drawings for all commissioned systems for which flow drawings exist. [By Trade Subcontractors]

4. Seasonal start-up and shutdown, manual and restart operation procedures. [By Trade Subcontractors.]

5. Complete as-built Control Drawings with points list, valve schedules, schematics, control system architecture and full sequences of operation (see example sequence of operation for rigor and format as a supplement to this Section). [By Trade Subcontractors.]

6. A description of and rationale for all energy and water saving features and strategies with operating instructions and caveats about their function and maintenance relative to energy use. [By CA.]

7. Recommendations for recalibration frequency of sensors and actuators by type and use. [By CA.]

8. Plans for continuous commissioning or recommended frequency for recommissioning by equipment type with reference to tests conducted during initial commissioning. [By CA.]

9. Description of the primary recommended standard trend logs in the control system that will assist in maintaining comfort, energy efficiency and system control. This will include sample plots with explanations of what to look for in the graphs. [By CA.]

10. Specific recommendations regarding seasonal operational issues that affect energy use. [By CA.]

11. A list of all user adjustable setpoints and reset schedules with a discussion of the purpose of each and the range of reasonable adjustments with energy implications. Include a schedule frequency to review the various setpoints and reset schedules to ensure they are at current relevant and efficient values. [By CA.]

12. A list of time of day schedules [by Trade Subcontractors] and a schedule frequency to review them for relevance and efficiency [by CA].

13. Guidelines for establishing and tracking benchmarks for whole building energy use and primary plant equipment efficiencies. [By CA.]

14. Guidelines for ensuring that future renovations and equipment upgrades won't result in decreased energy efficiency and maintaining the final design intent. [By CA.]

15. A list of diagnostic tools, with a description of their use, that will assist facility staff in operating equipment more efficiently. [By CA.]

a. Troubleshooting table for ongoing achievement of the University's project requirements and system performance [By CA].

b. Systems to be included in the Systems Manual: All the systems listed in this Section as being commissioned.

F. O&M Documentation Completion and Review:

1. The Commissioning Authority will provide an O&M Manual Checklist that lists the elements of the manuals required by the specifications. The Trade Subcontractors shall fill out this checklist for each manual and submit with the manual.

2. Prior to substantial completion, the Commissioning Authority shall review the O&M manuals for systems that were commissioned to verify compliance with the Specifications. This verification will be conducted by sampling the manuals against the O&M Manual Checklist. The Commissioning Authority will communicate deficiencies in the manuals to the University and the Architect. If systemic deficiencies are found, the Trade Subcontractors shall go back through those checklist items on every manual and verify compliance.

3. Upon a successful review of the corrections, the Commissioning Authority will recommend approval and acceptance of these sections of the O&M manuals.

4. The Commissioning Authority will also review each equipment warranty and verify that all requirements to keep

the warranty valid are clearly stated.

5. This work does not supersede the Architect's review of the O&M manuals.

G. Summary of Written Work Products: Written work products generated as part of the commissioning process are described in various parts of the Specifications and in the Commissioning Plan. In summary, the written products are:

	Product	Developed By
1.	University requirements and objectives	Architect per University Project Design Requirements
2.	Design narratives and design basis	Architect
3.	Final commissioning plan	Commissioning Authority
4.	Commissioning meeting minutes	Commissioning Authority
5.	Commissioning schedules	University and CMGC with input from the Commissioning Authority
6.	Special equipment/assembly submittals	Trade Subcontractors
7.	Sequence clarifications	Trade Subcontractors and Architect, as needed
8.	Construction checklist forms	Trade Subcontractors
9.	Start-up and initial checkout plan	Trade Subcontractors with review by Commissioning Authority
10.	Construction checklists, start-up and initial checkout forms	Filled out by Trade Subcontractors
11.	Emergency power and fire alarm response matrix.	Format by Commissioning Authority and content by Trade Subcontractors and Architect
12.	Issues Log	Commissioning Authority
13.	Commissioning Progress Record	Commissioning Authority
14.	Test forms	Commissioning Authority and Trade Subcontractors
15.	Filled out tests	Commissioning Authority and Trade Subcontractors
16.	Commissioning Record	Commissioning Authority
17.	Overall training plan	Trade Subcontractor for review by Commissioning Authority and University
18.	Specific training agendas and record	Commissioning Authority and Trade Subcontractors
19.	Systems Manual	Commissioning Authority

3.8. TRAINING OF University PERSONNEL

A. The Trade Subcontractors are responsible to provide training for University personnel per the Contract Documents. The Trade Subcontractors shall work with the Commissioning Authority to develop appropriate training and orientation agendas for equipment and assemblies and provide skilled trainers for the sessions. The Commissioning Authority will ensure that the Trade Subcontractors execute training per the Contract Documents and will provide a brief system overview at the beginning of the training sessions for the primary equipment. The training program is described in Division 01, Section 017900, Demonstration and Training.

3.9. STATIC ELEMENTS COMMISSIONING

A. The following tasks constitute the commissioning of the listed LEED static elements.

B. Water Use Reduction Credit 3. Static features (shower and faucet aerators, low flow fixtures, etc.) will have submittals reviewed by the University to verify that they meet the specified LEED standards. The Commissioning Authority verifies that submittals were approved by the University or Architect. The University or Architect performs site observation to ensure that submitted products were installed properly.

C. Energy and Atmosphere Features. The static energy features (wall, roof and pipe insulation, and the envelope assembly, including windows and doors) for the energy Credit 1 will have submittals reviewed for compliance with the specifications by the Architect. The Commissioning Authority verifies that submittals were approved by the University or Architect. The University or Architect performs site observation to ensure that submitted products were installed properly according to good thermal practice for air and water leakage potential.

D. IAQ management plan (Credit 3.1 and 3.2) features (IAQ management plan and building flush-out): Not explicitly required to be commissioned in LEED, but for this project the Commissioning Authority will review the CMGC's submittal of means and methods of the plan and ensure that a party has been assigned responsibility by the CMGC to monitor compliance with the plan.

E. Indoor chemical and pollutant source control (Credit 5) features. Entry-way systems, isolation and ventilation of house-keeping rooms, copy rooms and other chemical containing spaces and plumbing systems serving chemical mixing will receive on-site observations by the Commissioning Authority to verify that specified and submitted features are installed and operating properly. The isolation rooms or rooms with required differential pressures will be verified through testing when specified in Division 01, Section 013513.13, Cleanroom Certification and Acceptance.

F. Envelope air and moisture control design and integrity. Differential pressures will be measured between inside and outside to ensure the building is positively pressurized at the envelope. See test requirements in Division 01, Section 013513.13, Cleanroom Certification and Acceptance.

3.10. SUPPLEMENTS

A. The supplements listed below, and attached following “END OF SECTION,” are a part of this Specification:

1. Supplement 1- Representative Construction Checklist
2. Supplement 2-Sample Tests
3. Supplement 3- Check & Testing Responsibility Tables
4. Supplement 4- Sample Sequence of Operation

END OF SECTION 019113

SECTION 019113 - GENERAL COMMISSIONING REQUIREMENTS

SUPPLEMENT 1

REPRESENTATIVE CONSTRUCTION CHECKLIST

The following checklist is a sample of the type, format and rigor of mechanical check lists that will be used for this Project. Electrical equipment component checks are considerably simpler than this mechanical example and are given in the 1999 NETA Acceptance Testing Specifications for Electric Power Distribution "Visual and Mechanical Inspection" section of each equipment type.

Construction Checklist

Project

CC- AIR HANDLER UNIT (AHU) #s_____

Components included: Supply fans, return and exhaust fans, coils, valves, VFDs, dampers

Associated Checklists: Hydronic Piping, Hydronic Pumps, Chiller, Boiler,

1. Submittal/Approvals

Submittal: The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible Sub-Subcontractor. This construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed.___ List attached.

Mechanical Sub-Subcontractor	Date	Controls Sub-Subcontractor	Date
Electrical Sub-Subcontractor	Date	Sheet Metal Sub-Subcontractor	Date
Sub-Subcontractor	Date	SUBCONTRACTOR	Date

Construction checklist items are to be completed as part of startup and initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer’s recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- SUBCONTRACOR’s assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their sub-subcontractors are completed and checked off.
- “Contr” column or abbreviations in brackets to the right of an item refer to the Sub-subcontractor responsible to verify completion of this item. A/E = architect/ENGINEER, All = all Sub-subcontractorS, CA = commissioning agent, CC = controls Sub-subcontractor, EC = electrical Sub-subcontractor, GC = general Sub-subcontractor, MC = mechanical Sub-subcontractor, SC = sheet metal Sub-subcontractor, TAB = test and balance Sub-subcontractor

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Authority	Date	OWNER’s Representative	Date

2. Requested Documentation Submitted

Check if Okay. Enter comment or note number if deficient.

Check Equipment Tag-->						Trade
Manufacturer's cut sheets						
Performance data (fan curves, coil data, etc.)						
Installation and startup manual and plan						
Sequences and control strategies						
O&M manuals						

- Documentation complete as per contract documents for given trade..... ___ YES ___ NO

3. Model Verification [Trade = _____]

1 = as submitted, 2 = as installed. Check if Okay. Enter note number if deficient.

Equipment Tag-->					
1					
Mfr . 2					
1					
Model 2					
Serial 2					
1					
Capacity 2					
1					
Volts/Ph/A 2					

- The equipment installed matches the specifications for given trade ..... ___ YES ___ NO

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check Equipment Tag-->						Trade
Cabinet and General Installation						
Permanent labels affixed, including for fans						
Casing condition good: no dents, leaks, door gaskets installed						
Maintenance access acceptable for unit and components						
Access doors close tightly – no leaks						
Boot between duct and unit tight and in good condition						
Vibration isolation equipment installed & shipping locks released						
Maintenance access acceptable for unit and components						
Sound attenuation installed						
Thermal insulation properly installed and according to specification						
Instrumentation installed according to specification (thermometers, pressure gauges, flow meters, etc.)						
Clean up of equipment completed per contract documents						
Construction or final filters installed						
Filters clean and tight fitting						
Valves, Piping and Coils (see full piping checklists)						
Hydronic piping and pump construction checklists completed						
Pipe fittings complete and pipes properly supported						
Coils piped in proper direction						
Pipes properly insulated and labeled						
Strainers in place and clean						
Piping system properly flushed						
No leaking apparent around fittings						
All coils are clean and fins are in good condition						
All condensate drain pans clean and slope to drain, per spec						

Check if Okay. Enter comment or note number if deficient.

Check Equipment Tag-->						Trade
Valves properly labeled						
Valves positively verified to be installed in proper direction						
OSAT, MAT, SAT, RAT, chilled water supply sensors properly located and secure (related OSAT sensor shielded)						
Sensors calibrated (See calibration section below)						
Motors: Premium efficiency verified (if specified)						
P/T plugs and isolation valves installed per drawings						
Fans and Dampers						
Supply fan and motor alignment correct						
Supply fan belt tension & condition good						
Supply fan protective shrouds for belts in place and secure						
Supply fan area clean						
Supply fan and motor properly lubricated						
Return/exhaust fan and motor aligned						
Return/exhaust fan belt tension & condition good						
Return/exhaust fan protective shrouds for belts in place and secure						
Return/exhaust fan area clean						
Return/exhaust fan and motor lube lines installed and lubed						
Filter pressure differential measuring device installed and functional (magnehelic, inclined manometer, etc.)						
All dampers close tightly						
All damper linkages have minimum play						
Low limit freeze stat sensor located to deal with stratification & bypass						

Check if Okay. Enter comment or note number if deficient.

Check Equipment Tag-->						Trade
Ducts (preliminary check)						
Sound attenuators installed						
Smoke and fire dampers installed per contract docs (proper location, access doors, duct breakaways and appropriate ratings)						
Duct joint sealant properly installed						
No apparent severe duct restrictions						
Turning vanes in square elbows as per drawings						
OSA intakes located away from pollutant sources & exhaust outlets						
Pressure leakage tests completed						
Branch duct control dampers operable						
Ducts cleaned as per specifications						
Balancing dampers installed as per drawings and TAB's site visit						
Electrical and Controls						
Pilot lights are functioning						
Power disconnects in place and labeled						
All electric connections tight						
Proper grounding installed for components and unit						
Safeties (especially high duct static) in place and operable						
Starter overload breakers installed and correct size						
Sensors calibrated (see below)						
Control system interlocks hooked up and functional						
Smoke detectors in place						
All control devices, pneumatic tubing and wiring complete						
Building static pressure sensors located to ensure good signal						

Check if Okay. Enter comment or note number if deficient.

Check Equipment Tag-->						Trade
Duct static pressure sensor properly located and per drawings & calibrated (> 70% down from fan to critical TU & >5 duct diameters upstream and > 10 duct diameters downstream from takeoffs, etc.)						
VFD						
VFD powered (wired to controlled equipment)						
VFD interlocked to control system						
Static pressure or other controlling sensor calibrated						
Drive location not subject to excessive temperatures						
Drive location not subject to excessive moisture or dirt						
Drive size matches motor size						
Internal setting designating the model is correct						
Input of motor FLA represents 100% to 105% of motor FLA rating						
Appropriate Volts vs. Hz curve is being used						
Accel and decel times are around 20-100 seconds, except for special applications. Actual decel = _____ Actual accel = _____						
Lower frequency limit at 10% for forward curved fans and 35% for airfoil fans, 50% for oil sleeve bearings and around 10-30% for chilled water pumps. Actual = _____						
Upper frequency limit set at 100%, unless explained otherwise						
Mixed air temperature low limit loop is programmed						
Unit is programmed with full written programming record on site						
TAB						
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents						
Final						
Smoke and fire dampers and TUs are open						

Check if Okay. Enter comment or note number if deficient.

Check Equipment Tag-->						Trade
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent (static pressure, relief doors, overloads, freeze stat, etc.)						
If unit is started and will be running during construction: have quality filters on RA grills, etc. to minimize dirt in the ductwork and coils and in any finished areas. Verify moisture migration is not a problem, due to improper pressures between spaces.						

- The checklist items of Part 4 are all successfully completed for given trade. ..... ___ YES ___ NO

5. Operational Checks (These augment manufacturer's list. This is not functional testing.)

Check if Okay. Enter comment or note number if deficient.

Check Equipment Tag-->						Trade
Supply fan rotation correct						
Return/exhaust fan rotation correct						
Fans > 5 Hp Phase Checks: (%Imbalance = 100 x (avg. - lowest) / avg.) Record all 3 voltages in cell. Imbalance less than 2%?						
Record full load running amps for each fan. _____rated FL amps x _____service factor = ____ (Max amps). Running < max?						
Return /exhaust fan acceptable noise & vibration						
Supply fan has no unusual noise or vibration						
Inlet vanes aligned in housing, actuator spanned, modulate smoothly and proportional to input signal and EMS readout						
All dampers (OSA, RA, EA, etc.) stroke fully without binding and spans calibrated and BAS reading site verified (follow procedure in Calibration and Leak-by Test Procedures). List dampers checked: _____						
Valves stroke fully and easily and spanning is calibrated (follow procedure in Calibration and Leak-by Test Procedures). List each actuated valve here when spanned:_____						
Valves verified to not be leaking through coils when closed at normal operating pressure (follow procedure in Calibration and Leak-by Test Procedures).						

Check if Okay. Enter comment or note number if deficient.

Check Equipment Tag-->						Trade
Restoration of power won't over-pressurize duct from closed FSDs						
The HOA switch properly activates and deactivates the unit						
Specified sequences of operation and operating schedules have been implemented with all variations documented						
Specified point-to-point checks have been completed and documentation record submitted for this system						
Final filters installed and replacement type and efficiency permanently affixed to housing—construction filters removed						
Startup report completed with this checklist attached						

6. Coil Fouling. Trade: [ ]

Verify that the AHU cooling and heating coils are not fouled by: Take pressure drop readings across the coils from the TAB report and plot on the manufacturer's charts to determine what the gpm should be at those pressure drops. Compare those gpms to the ones measure with the TAB's flow meter. If the actual flow from the TAB meter is more than 10% less than that expected (as found on the manufacturer's differential pressure chart), assume that there is clogged strainer or fouled coils. Record below.

	AHU _____		AHU _____		AHU _____		AHU _____	
	Cooling Coil	Htg Coil	Cooling Coil	Htg Coil	Cooling Coil	Htg Coil	Cooling Coil	Htg Coil
Differential Pressure								
Flow from Mfgr's Chart								
Flow from TAB meter								
% TAB reading is low from Mfr Chart								
Within 10%?								
Strainer checked and found clean?								

Record were readings were taken: _____

- The checklist items of Part 5 are all successfully completed for given trade. .....___ YES ___ NO

7. Sensor and Actuator Calibration Trade: [ ]

All field-installed temperature, relative humidity, CO, CO2 and pressure sensors and gauges, and all actuators (dampers and valves) on this piece of equipment shall be calibrated using the methods and tolerances given in the Calibration and Leak-by Test Procedures document. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated.

Sensor or Actuator & Location	Loc-ation OK	1st gauge or BAS Value	Observ or Instr. Meas'd Value	Final Gauge or BAS Value	Pass Y/N?

Sensor & Lo-cation	Loc-ation OK	1st Gauge or BAS Value	Observ or Instr. Meas'd Value	Final Gauge or BAS Value	Pass Y/N?

Gauge reading = reading of the permanent gauge on the equipment. BAS = building automation system. Instr. = testing instrument. Visual = actual observation. The SUBCONTRACTOR's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the referenced procedures are followed.

- All sensors are calibrated within required tolerances .....___ YES ___ NO

END OF SUPPLEMENT 1 to SECTION 019113

SECTION 019113 – GENERAL COMMISSIONING REQUIREMENTS

SUPPLEMENT 3

CHECK AND TESTING RESPONSIBILITY TABLES

PART 1 - GENERAL

1.1 SUMMARY

A. In general, the HVAC and control system test procedures are written and their execution directed by the Commissioning Authority. For some electrical equipment and for clean room and laboratory equipment, the test responsibility is, as listed in the table, distributed between the Trade Subcontractor, the CMGC, the manufacturer's service representative, a certified electrical testing company and the design engineer (A/E). All test procedures are approved prior to execution by the Commissioning Authority.

B. Construction Checklists are primarily visual checks / inspections of static conditions, but for some equipment may include initial checkout, calibration and operational checks. Tests are executed after the checklists and include measurements and sequence of operation verifications.

C. Abbreviations:
1. A/E: Designer
2. CA: Commissioning Authority
3. TC: Trade Subcontractor providing equipment
4. CC: Controls Contractor
5. EC: Electrical Contractor
6. CTC: Certified Testing Company (provided by the Trade Subcontractor)
7. MC: Mechanical Contractor
8. MSR: Manufacturer Service Representative
9. U: UNIVERSITY
10. RA: Regulatory Authorities
11. SI: Special Inspector (hired directly by the UNIVERSITY)
12. TAB: Testing, Adjusting and Balancing contractor

D. Column Heading Key:
1. Submittal Review: Review submittals of commissioned equipment for either information to assist in test writing and field verification (designated by an (I) in the table), or for a more thorough review to make comments parallel with the A/E reviews (R).
2. Field Observation: General observation of installation to become familiar with equipment and secondarily to identify problems.
3. Prepare Construction Checklists and/or Startup Plan: The first indicated party is responsible to develop written checks to ensure proper installation and setup. A "$" indicates that a checkout and startup plan is also required to be developed by the adjacent indicated party and used by the Trade Subcontractor. This is a written plan for conducting and documenting installation, startup, and checkout and shall include specific startup sequence instructions. The startup plan will be used to energize both electrical and mechanical equipment. The Construction Checklist is a part of this Plan.
4. Perform and Document Checklists: The first indicated party is responsible to execute the checklists and document each line item. The CA spot-witnesses checklisting and startup and reviews the completed versions (reports). Any Construction Checklists or Startup Plans developed by the CA are reviewed by the Trade Subcontractors and vise-versa prior to execution.

   * indicates that the Construction Checklist is included in the Specifications for this equipment, but needs to be transferred to a formal documentation check sheet form by the indicated party executing the checklist.

   % indicates that the party adjacent to the symbol will be verifying critical elements and components against the construction documents, in addition to the indicated party fully documenting the checklist and startup form.

5. Prepare Test Procedures: Develop the written step-by-step test procedures and documentation forms for mechanical systems. For electrical component tests, these procedures may be more checklist in nature and not include all specific procedural details, though all measurements will be recorded.
6. Review Test Procedures: Review and approve test procedures developed by others.
7. Coordinate, Oversee and Document Tests.
8. Ensure that tests are scheduled and coordinated with the interfaces to other systems and requirements of the authorities having jurisdiction.
9. Develop a logical test plan that flows from the component level on the various systems to the integrated testing of the systems as they interact with each other.
10. Direct the order that test procedures are conducted. Coordinate and manage the parties participating in the testing.
11. Verify that all necessary documentation requirements are met for all parties including but not limited to authorities having jurisdiction, the UNIVERSITY, the Commissioning Authority and the insurance underwriter.
12. Facilitate effective communication and coordination across trades and disciplines as required for successful integrated testing of systems and assemblies.
13. Witness entire test and fully document on approved forms the methods, procedures, and results of each test procedure for all tests.
14. Perform Test: Manipulate equipment or systems or set up and initiate actions on assemblies that demonstrate function and performance.
15. Witness: (See also applicable footnotes.)
    a. Spot ((S) in the table): Spot witnessing of testing shall include a large enough sample to provide reasonable confidence that the tests were conducted properly. Sampling may be random or focused as determined by the Commissioning Authority. For selected systems such as duct and pipe pressure testing, spot witnessing may only require reviewing means and methods at the beginning of the test and a review of the test report.
    b. All ((A) in the table): Witness the duration of all test procedures performed. Note that for some systems where there is a sampling strategy, not all systems will be tested, but all that are tested will be witnessed. Refer to the testing requirements in the referenced Sections for details.
    c. Witnessing does not necessarily include documenting of individual test or observation results, but does include recording attendance and general results.
16. Review Test Report: Review the testing documentation. See also applicable footnotes.

Check and Testing Responsibility Table (Refer to Key above.)

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor-mation or Review) [3]	2 Field Obser-vation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Check Lists and Manufac-turer Start Up Forms	5 Prepare Test Proce-dures	6 Review Test Proce-dures	7 Coordinate, Oversee & Document Test	8 Perform Test	9 Witness Test [1] (Spot or All)	10 Re-view Test Report [2]
MECHANICAL SUPPORT SYSTEMS											
Chilled Water System (A)	Chillers (3), cool-ing towers, pumps; controls	R-CA	CA; U	CA; $TC/MSR	TC	CA	MC, CC	CA	MC; CC	A-CA; U	U
Heating Water System (A)	Boilers (2); pumps and con-trols	R-CA	CA; U	CA; $TC/MSR	TC	CA for function-al and MSR for perfor-mance tests	" "	CA for functional and MSR for perfor-mance tests	MC; CC; MSR	" ", ex-cept S-CA for perfor-mance tests	U; CA
Hydronic Piping	All	None	CA; U	CA; $TC/MSR	TC	none	NA	MC	MC	S-U; CA	CA
Air Handlers (B)	All (2)	R-CA	CA; U	CA; $TC/MSR	TC	CA	MC, CC	CA	MC, CC	A-CA; U	U
Air Terminal Units (C)	All	I-CA	CA; U	CA; $TC/MSR	TC	CA	MC, CC	CA	MC, CC	S-CA; U	U
Duct Leakage Tests		None	none	none	None	none	NA	MC	MC	S-U	CA
Exhaust and Make-up Fans (non-cleanroom or lab) (C)	All (8)	I-CA	CA; U	CA; $TC/MSR	TC	" "	" "	" "	" "	" "	" "
FMCS System/ BAS / BMS (non-cleanroom or lab) (B)	All	R-CA	CA; U	CA; $TC/MSR	TC	CA	CC	CA	CC	A-CA;U	U
TAB Spot Check (B)	Test and balance work.	See Plan, Col 3	U	CA; $TC (refer to Section 230593)	TC	CA	TAB	CA	TAB	S-CA;U	" "

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor-mation or Review) [3]	2 Field Obser-vation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Check Lists and Manufac-turer Start Up Forms	5 Prepare Test Proce-dures	6 Review Test Proce-dures	7 Coordinate, Oversee & Document Test	8 Perform Test	9 Witness Test [1] (Spot or All)	10 Re-view Test Report [2]
Vibration Testing	Fans, cooling tower, motors and other equipment with vibration cri-teria given.	NA	NA	NA	NA	NA	NA	TAB	TAB	S-CA; U	CA, U; AE
Envelope / HVAC Interactions (B)	All	None	CA; U	CA	TC	CA	TAB	CA	TAB; CC	A-CA	" "
Fire Protection Systems	Fire smoke dampers, damp-ers, and sequenc-ing of shutdown.	R-CA	CA; U	CA	TC	CA	MC, CC	CA	MC; CC	A-CA; U	U
LAB and CLEANROOM MECHANICAL											
Makeup AHUs (A) (cleanrooms)	(1) Fans, motors, drives, dampers, valves, coils, con-trols, etc.	R-CA	CA; U	CA; $TC/MSR	TC; %U	CA	TC	CA; U	TC	A-CA; U	U; AE
Fan filter units (B) (cleanroom) See also Part 2 below	(210) Units, filters, racks and controls	I-CA	CA; U	CA	TC; %U	CA	TC	CA; U	TC	S-CA; U	U; AE
Duct leakage tests	Ducts	None	none	none	None	None	NA	MC	MC	S-O	CA
Process exhaust systems (B)	(2) Fans, ducts,	I-CA	CA; U	CA	TC; %U	CA	C	CA; U	TC	A-CA	U; AE
Fume hoods	(54) Hoods, fans, valves, controls	I-CA	CA; U	CA	TC; %U	MSR; CTC	CA; U	TAB	CTC	S-CA; U	CA, U; AE
Snorkel exhaust devices	(2) Fans, damp-ers, controls	I-CA	CA; U	CA	TC; %U	MSR; CTC	CA; U	TAB	CTC	S-CA; U	CA, U; AE
Bio-safety cabinets	(1) Dampers, ducts, controls	I-CA	CA; U	CA	TC; %U	TC,CTC	NA	CTC	CTC	S-CA; S-U	CA, U; AE

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor-mation or Review) [3]	2 Field Obser-vation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Check Lists and Manufac-turer Start Up Forms	5 Prepare Test Proce-dures	6 Review Test Proce-dures	7 Coordinate, Oversee & Document Test	8 Perform Test	9 Witness Test [1] (Spot or All)	10 Re-view Test Report [2]
Misc. exhausted safety cabinets	(40) Dampers, ducts, controls	I-CA	CA; U	CA	TC; %U	NONE	NA	STD TAB Only	--	S-CA; S-U	CA, U; AE
Split AC unit (B) (cold rooms)	(2) Evaporator, condenser, heat exchanger	I-CA	CA; U	CA	TC; %U	CA	TC	TC	TC	A-CA	U; AE
TAB Spot Check (C) (labs and cleanrooms)	Testing and bal-ancing work	See Plan, Col 3	CA; U	CA	TC	CA	TC	CA; U	TAB	A-CA; U	U; AE
Controls (B) (lab and cleanrooms) See also Part 2 Below	FMCS, MCS and equipment con-trols	R-CA	CA; U	CA	TC; %U	CA	TC	CA; U	TC	A-CA; U	U; AE
Cleanroom certification See also Part 2 Below	Cleanrooms	See Plan Col 3	CA; U	CA; $CTC	TC; CTC	CTC with input from CA	CA	CTC	CTC	S-CA; U	CA; U; AE
Vibration Testing	FFU	NA	NA	NA	NA	NA	NA	Factory (test 15%)	Factory	None	CA; AE; U
LAB and CLEANROOM PROCESS											
Treated Water (B)	Pumps, filters, heat exchanger	I-CA	CA; U	CA	TC	CA	TC	CA	TC	A-CA; U	AE
RO/DI Water and Delivery	Tanks, pumps, filters, reverse osmosis, deioniz-ers, UV, piping and valves	R-CA	CA; U	CA	TC	CTC	CA	CTC	CTC	S-CA; U	CA
Bulk Gases Storage and Delivery (Nitrogen, Process Nitrogen)	Cylinders, dewars, bulk LN2 tank, piping and valves	I-CA	CA; U	CA	C; CTC	CTC	CA	CTC for UHP pip-ing; C	CTC	S-CA; U	CA
High Purity Specialty Gas Storage and Delivery	Gas cabinets, valve manifold boxes, cylinders, piping and valves	I-CA	CA; U	CA	TC	CTC	CA	CTC	CTC	S-CA; U	CA

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor-mation or Review) [3]	2 Field Obser-vation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Check Lists and Manufac-turer Start Up Forms	5 Prepare Test Proce-dures	6 Review Test Proce-dures	7 Coordinate, Oversee & Document Test	8 Perform Test	9 Witness Test [1] (Spot or All)	10 Re-view Test Report [2]
Vacuum System (B)	Pumps, receiver	I-CA	CA; U	CA	TC	CA	TC	CA	TC	S-CA; U	CA
Oil-Free Compressed Dry Air), and Process Air (A)	Compressor, re-ceiver, dryer, fil-ters	I-CA	CA; U	CA	TC	CA	TC	CA	TC	S-CA; U	CA
Bio Waste Sterilization	Autoclaves	I-CA	CA; U	CA	TC	MSR	CA	MSR	MSR	S-CA; U	CA
Bio Media Preparation	Autoclaves	I-CA	CA; U	CA	TC	MSR	CA	MSR	MSR	S-CA; U	CA
Bio Glassware Cleaning	Dishwasher, dry-ing oven, auto-clave	I-CA	CA; U	CA	TC	MSR	CA	MSR	MSR	S-CA; U	CA
ELECTRICAL											
Scheduled Lighting Controls (B)	All	I-CA	CA; U	CA; CTC; $MSR	TC	CA	TC	CA	TC;CTC ;MSR	A-CA; U	AE; U
Lighting Occupancy Sensors (B)	All	I-CA	CA; U	CA	TC	CA	TC	CA	TC;CTC ;MSR	S-CA; U	AE; U
Emergency Generator, ATS, and Load Banks	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	TC;MSR	CTC;MS R	A-CA; S-U; S-AE	AE; U
Medium/Low Voltage Switchgears	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	TC;MSR	CTC;MS R	A-CA; S-U; S-AE	AE; U
Transformers	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	TC;MSR	CTC;MS R	S-CA; U; AE	AE; U
Substations	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	TC;MSR	CTC;MS R	S-CA; U; AE	AE; U
Uninterruptible Power Supply (UPS)	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	TC;MSR	CTC;MS R	A-CA; S-U; S-AE	AE; U
Panel Boards, Switch-boards	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	TC;MSR	CTC;MS R	S-CA; U; AE	AE; U
Photovoltaic and Fuel Cells	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	TC;MSR	CTC;MS R	S-CA; U; AE	AE; U

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor-mation or Review) [3]	2 Field Obser-vation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Check Lists and Manufac-turer Start Up Forms	5 Prepare Test Proce-dures	6 Review Test Proce-dures	7 Coordinate, Oversee & Document Test	8 Perform Test	9 Witness Test [1] (Spot or All)	10 Re-view Test Report [2]
Power and energy meters	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	MSR	MSR	S-CA; U; AE	AE; U
VFD	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	TC;MSR	TC;MSR	A-CA; S-U; S-AE	AE; U
FIRE AND LIFE SAFETY											
Fire Alarm	All	R-CA	CA; U;RA	CA	TC	TC;MSR	CA;RA	TC	TC;MSR	A-CA; A-RA/U	AE; U
Fire Protection	Stand pipe, valves; controls	R-CA	CA; U;RA	CA	TC	TC;MSR	CA;RA	TC	TC;MSR	A-CA; A-RA/U	AE; U
Emergency Egress Light-ing	All	R-CA	CA; U;RA	CA	TC	TC;MSR	CA;RA	TC	TC;MSR	A-CA; A-RA/U	AE; U
VESDA (if applicable)	All	R-CA	CA; U;RA	CA	TC	TC;MSR	CA;RA	TC	TC;MSR	A-CA; A-RA/U	AE; U
Public Announcement	All	R-CA	CA; U;RA	CA	TC	TC;MSR	CA;RA	TC	TC;MSR	A-CA; A-RA/U	AE; U
BUILDING AUTOMATION SYSTEMS AND CONTROLS											
Building Automation Sys-tem	All	R-CA	CA; U	CA; $TC	TC	CA	CC	CA	CC	A-CA;U	U
SECURITY											
Security Access & Controls	All	R-CA	CA; U	CA; $TC	TC	CA	TC	CA	TC	A-CA;U	U
METERING											
Power and Electricity Me-ters, including end-use electricity sub-metering, and connection to ION Enterprise	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	CA	TC;CTC ;MSR	S-CA; U; AE	AE; U

System or Assembly	Components (assumed QT's in ())	1 Submittal Review (Infor-mation or Review) [3]	2 Field Obser-vation [3]	3 Prepare Const. Checks and/or $Plan	4 Perform & Document Check Lists and Manufac-turer Start Up Forms	5 Prepare Test Proce-dures	6 Review Test Proce-dures	7 Coordinate, Oversee & Document Test	8 Perform Test	9 Witness Test [1] (Spot or All)	10 Re-view Test Report [2]
Water Meters, including flow and energy meters such as BTUh meters, and connection to BMS/BAS	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	CA	TC;CTC ;MSR	S-CA; U; AE	AE; U
Gas Meters (if applicable) including connection to BMS/BAS	All	R-CA	CA; U	CA; CTC; $TC/MSR	TC	CA	TC	CA	TC;CTC ;MSR	S-CA; U; AE	AE; U

Notes:
(A), (B), and (C) Testing Type: For each piece of equipment or system where the CA will direct the execution of the functional test, the test has been assigned an approximate level of complexity for reference. Where there is no Code, the complexity of testing is not dictated by the CA. Sample test procedure forms that are representative of these levels are found in Supplement 2.

A blank cell with a – or a "none" indicates this activity is not required.
[1] The Architect or design engineers may witness tests per their scope.
[2] The Architect or design engineers may review completed test procedures if in their scope.
[3] AE reviews all submittals and observes construction according to their contract.

The following systems are not part of Day 1 Construction and are excluded from this scope: Hot DI Water, AWN, Solvent Waste, Metal Waste, Breathing Air, Scrubbed Exhaust, High Purity Liquid Chemicals, and VOC abatement.

PART 2 - CLEAN ROOM TESTING

	Functional Test		Spot Check		
	% Tested	Directed By [4]	% Checked	Directed By	Note
Fan Filter Units (FFU)					
Flow rate and adjustment to design	100%	TAB	10%	CA	Refer to Section 230593.
FFU vibration, noise, power, pressure drop; EMI	15% for vibration, noise, pwr; dP; 20% for EMI	By factory, at factory	0	NA	
Room pressurization setup and control setpoints	100%	TAB	see MCS	CA	Refer to Section 230593.
FFU Monitoring Control System (MCS)					
Verify all functions and features [1]	All	Directed by CA, executed by CC	none	--	
Clean Room Certification Preparation					
FMCS	All areas affecting cleanroom	Directed by CA, executed by CC	None	NA	
TAB of support areas adjacent to clean room	All	TAB	10%	CA	
TAB of MAU air and water	All	TAB	10% of air	CA	
TAB of clean room – See FFU					
Sound measurements	Per Drawing CRA0.4	TAB	None	NA	Required in Section 013513.13.
Clean Room Certification (refer to Section 013513.13)					
FFU filter edge leakage	All	CTC	SW [2]	CA	
Filter challenge	All	CTC	SW [2]	CA	
Particle counts	Entire room	CTC	SW [2]	CA	
Airflow (velocity; laminarity)	Entire room	CTC	SW [2]	CA	
Temp	Entire room	CTC	RT [3]	CA	

	Functional Test		Spot Check		
	% Tested	Directed By [4]	% Checked	Directed By	Note
RH	Entire room	CTC	RT [3]	CA	
ESD (electrostatic discharge and grounding)	Entire room	CTC	RP [3]	CA	
Floor conductivity test	Entire room	CTC	SW [2]	CA	
Electromagnetic interference (EMI)	Entire room	CTC	SW [2]	CA	Refer to Section 013513.13.
Noise	Entire room	CTC	SW [2]	CA	Refer to Section 013513.13.
Lighting	Entire room	CTC	SW [2]	CA	Refer to Section 013513.13.

Notes:
[1] Note used.
[2] CA spot witnesses certification (SW)
[3] CA reviews trend (RT) / monitoring reports (RP) from CTC.
[4] Directed and executed by.

END OF SUPPLEMENT 3 to SECTION 019113

SECTION 019113 - GENERAL COMMISSIONING REQUIREMENTS

SUPPLEMENT 2

SAMPLE TESTS

TEST 1 OF 3. TYPE: A-COMPLEX

Project _____

FT- CHILLERS 1 thru 3

And Chiller System Including:
Cooling Towers 1 thru 3
CHW Pumps 1 thru 8, including variable speed drives
CD Pumps 1 thru 9 and Piping
HE-1 (heat exchanger)

Related Tests: _____

A. Participants:

Party	Participation
_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Dates of tests _____

Dates of tests _____

Dates of tests _____

Dates of tests _____

B. Test Prerequisites

1. The following have been started up and startup reports* and prefunctional checklists submitted and approved ready for functional testing:

__ Chiller __ Condenser water pumps

__ Chilled water pumps __ Chilled water piping and valves

__ Cooling towers __ Variable speed drives for pumps

*The written chiller startup report must contain a full listing of all adjustable internal program settings.

2. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed. _____ _____

3. Controls Contractor Signature or Verbal Date

4. __ Piping system flushing complete and required report approved.

5. __ Water treatment system complete and operational.

6. __ Vibration control report approved (if required).

7. __ Test and balance (TAB) complete and approved for the hydronic system.

8. __ All A/E punchlist items for this equipment corrected.

9. __ These functional test procedures reviewed and approved by installing contractor.

10. __ Safeties and operating ranges reviewed.

11. __ Test requirements and sequences of operation attached.

12. __ Schedules and setpoints attached.

13. __ False loading equipment, system and procedures ready (cross-over piping, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)

14. __ Sufficient clearance around equipment for servicing.

15. __ Sump or crankcase heaters have been on long enough to allow immediate starting of chillers.

16. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this chiller and control system are capable of? If not, list recommendations below.

17. __ Control Program Review. Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.

18. __ Record made of All Values for Current Setpoints (SPt), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accomodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Space Temp. Setpts		
AHU economizer damper and changeo-ver settings		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Primary CHW Pumps CHWP-1 CHWP-2 CHWP-3 CHWP-4 CHWP-5 (hand, off, auto)		
Manual piping & valving for standby PCHWP		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
AHU preheat coil valve (auto, manual)		
Min. OSA preheat coil DAT setpoint		
Boiler enable, heating water temp. etc.		
CHWS SPt temp		
Lead chiller ID: Lag 1 ID: Lag 2 ID:		
Lead CD pump ID: Lag 1 ID: Lag 2 ID:		
Safety Overrides		
Lead CHW pump ID: Lag 1 ID: Lag 2 ID:		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
EF-10 (hand, off, auto)		
Secondary CHW Pumps CHWP-6 CHWP-7 CHWP-8 (hand, off, auto)		
Condenser Pumps CDP-1 CDP-2 CDP-3 CDP-4 CDP-5 CDP-6 CDP-7 CDP-8 CDP-9 (hand, off, auto)		
VFD CHWP-6 CHWP-7 CHWP-8 (hand, off, auto)		
Demand Limit CH-1: CH-2: CH-3:		
CT fans CT-1 CT-2 CT-3 (hand, off, auto)		
CT vibration sensors CT-1 CT-2 CT-3 (normal, jumped)		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Chillers: CH-1: CH-2: CH-3: (hand, off, auto)		
Chiller flow switches: CH-1: CH-2: CH-3: (normal, jumped)		
CHW diff. press. Spt Across pump: Out in system:		
Delays		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
CT sump overflow CT-1 CT-2 CT-3 (normal, plugged)		
CT makeup valve CT-1 CT-2 CT-3 (auto, manual)		
Occupied schedule Start Stop		

C. Sensor Calibration Checks. The sensors listed below checked for calibration and adequate location. This is a spot check on a sample of the calibrations done during prefunctional checklisting.*

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements. If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK1	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?
ECDWT					
Pump dP sensor					
CT-1 sump T.					

Sensor & Location	Location OK1	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?
CT-2 sump T.					
CHWST					

1Sensor location is appropriate and away from causes of erratic operation.
*For every sensor originally found out of calibration, check one additional sensor not listed.

D. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during prefunctional checklisting and startup.**

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	1st BAS Reading	Site Ob-serv-ation	Final BAS Reading	Pass Y/N
CHWP-6 rpm				
CHWP-7 rpm				
CHWP-8 rpm				

Device or Actuator & Location	1st BAS Reading	Site Ob-serv-ation	Final BAS Reading	Pass Y/N
CT-1	fan stage 1			
CT-1	fan stage 2			
CT-2	fan stage 1			
CT-2	fan stage 2			
CT-3	fan stage 1			
CT Bypass valve				

**For every actuator or device originally found out of calibration, check one additional one not listed.

E. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____

Notes on Methods Used to False Load Chiller (for reference, see Note 6 at end of test)
_____
_____
_____
_____
_____
_____

F. Seasonal Testing and General Conditions of Test:

Due to the building completion being during winter, this test will be completed in two stages. The first testing will occur prior to substantial completion, during cold weather. The objective of this first stage test is to provide reasonable assurance that the chiller will function properly during lower load conditions. This will prepare the chiller for operation during the beginning of the cooling season. As many of the test procedures as possible will be executed during this first test, through the use of the methods of false loading noted above and in Note 6 at the end of the test. Tests of all chillers close to full load and full cooling tower fan staging will not be able to be executed until summer. Chiller safeties will be tested prior to occupancy and cooling tower winter operation and sump heater tests will be performed during cold weather of the first test.

At the beginning of the cooling season, the chiller will be started and operated, without further testing, unless problems arise. Then, when conditions are warmer (approximately 80F-85F), the second test will be performed. This will likely require some false loading to create close to full load conditions and subsequently may need to be executed on a weekend to minimize discomfort to occupants. During this second test, some of the sequences performed during the first test will be retested and recorded, as necessary, to get to the staging and full load tests not performed during the first test. Also, the benchmarking and trending will be completed during the second test period.

G. Test Procedure Table of Contents

Procedure: #

H. Testing Procedures and Record:

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
CHILLER SYSTEM STARTUP AND STAGING					
1 Seq 1-4, 16, 20-23, 32	Specs 15682 3.3.; 15683 3.2	Startup Sequence. Lead = CH-____. (This is not the initial startup by factory reps). With chiller system off, with schedule allowing chillers ON and OSAT >56F, turn chillers and pumps to auto. Turn on AHUs and cause a call for cooling sufficient to call for chillers (see manually open preheat coil valve, lower space temperature SPt, etc. A call for the chillers will be made when any AHU fan is ON and its CCV is => 15% open for 10minutes. Vanes:	Observe that the lead primary CHW pump does not turn ON until a CCV on an ON AHU is => 15% [_____%] open for 10 min. [_____]. Observe lead secondary CHW pump start when a CCV is 15% [_____] open for 10 [_____] minutes. Observe CHW primary and secondary pumps turning on, then the oil pump; then the CD pump (30-60s delay ea.) Observe that secondary pumps start at minimum RPM and slowly ramp up. Starting RPM = [_____]. Observe the lead chiller starting. Observe that the vanes start closed and begin to open. (max spd = 0-full open in ~3 min. and closed in ~1 minute)		
1 cont. Seq 1-4, 16, 20-23, 32	 156823 .3.E	Cooling Tower: Specified Sequences: Poll ECDWT every 4 min. If > 2F above setpoint, increase CT stage by one. When < 1F below setpoint, lower CT stage one. Maintain chiller load between 10-15% for 30 minutes.	OSAT = [_____F]. OSAWB = [_____F]. Observe that when the lead chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPt of OSA wet bulb + 7F is maintained (within 65F to 83F). Observe that the bypass valve is closed when the setpoint is exceeded [_____]. Observe that the cooling tower successively stages up as the setpoint remains unsatisfied. Record results. Time Setpoint ECDWT CT Stage Observe that there is no surging or abnormal vibration.		

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
2 Seq 8	Specs 15682 3.3.; 15683 3.2	1st Lag Chiller Staging ON. Staging sequence: CH-___ -->CH-___ -->CH-___ With chillers in auto, and loaded such that only lead chiller is running, lower space setpoints so CCVs open. Wait ~10 minutes. Record time that primary flow and secondary flow become equal. Wait 20 minutes.	Total primary flow = [_____gpm]. Secondary CHW flow => primary CHW flow = [_____gpm] and lead chiller is at least 95% loaded (by % of rated current), [_____ amps]. Time: [_____]. After 20 minutes, 1st lag chiller should start (PCHWP - oil pump - CDP - chiller). Time when 1st lag chiller started = [_____]. Observe that the amps on both chillers are within 5% of each other.		
3 Seq 8; 32-34	Specs 15683 3.3.F.2	1st Lag Secondary CHWP Staging ON. Continue increasing cooling load, if necessary, to cause CCVs to open further.	Observe that after total SCHW flow [_____gpm, _____rpm] > total design flow of ON SCHW pumps (765 gpm), and the SCHW pump dP drops 2 psi [_____] below SPt for 10 minutes, the first lag SCHWP turns ON. Observe that the 2 pumps' rpm are aprox. equal and at aprox. 50% (880 rpm), [CHWP-_____ rpm, CHWP- _____ rpm] and that total flow is just over previous gpm (765) [_____gpm], and that after ~ 2 minutes, pump dP is maintained at SPt _____ [_____] and remote dP is maintained at SPt _____ [_____].		
4 Seq 8; 21-24	Specs 15682 3.3.; 15683 3.2	1st Lag Cooling Tower Staging ON. During the preceding sequences:	OSAT = [_____F]. OSAWB = [_____F]. Observe that the cooling tower successively stages up as the setpoint remains unsatisfied. Record results. Time Setpoint ECDWT CT Stage		
5 Seq 8	Specs 15682 3.3.; 15683 3.2	2nd Lag Chiller Staging ON Cont. After second chiller starts, continue calling for more cooling to start third chiller.	Total primary flow = [_____gpm]. Observe until secondary CHW flow => primary CHW flow = [_____gpm] and both chillers are at least 95% loaded (by % of rated current), [_____amps]. Time: [_____]. After 20 minutes, 2nd lag chiller should start (PCHWP - oil pump - CDP – chiller). Time when 2nd lag chiller started = [_____]. Observe that the amps on all running chillers are within 5% of each other.		

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
6 Seq 8; 32-34	Specs 15682 3.3.; 15683 3.2	2nd Lag Secondary CHWP Staging ON Cont. Continue increasing cooling load, if necessary, to cause CCVs to open further.	Observe that after total SCHW flow [_____gpm, CHWP- _____rpm, CHWP- _____rpm] is greater than total design flow of ON SCHW pumps (1530 gpm), and the SCHW pump dP drops 2 psi [_____] below SPt [_____], for 10 minutes, the 2nd lag SCHWP turns ON. Observe that the 3 pumps' rpm are aprox. equal and at aprox. 67% (1170 rpm), [CHWP- _____ rpm, CHWP- _____ rpm, CHWP- _____ rpm] and that total flow is just over previous gpm (1530) [_____gpm], and that after ~ 2 minutes, pump dP is maintained at SPt _____ [_____] and remote dP is maintained at SPt _____ [_____].		
7 Seq 8; 21-24	Specs 15682 3.3.; 15683 3.2	2nd Lag Cooling Tower Staging ON. During the preceding sequences:	OSAT = [_____F]. OSAWB = [_____F]. Observe that the cooling tower successively stages up as the setpoint remains unsatisfied. Record results. Time Setpoint ECDWT CT Stage		

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
8 Seq 9, 10; 35	Specs 15682 3.3.; 15683 3.2	Chillers Staging OFF. Raise space setpoints so CCVs close, or shut off some or all AHU's. Wait ~5 minutes. Record time that primary flow exceeds secondary flow by capacity of last selected pump. Wait thru any delay. (CHWP 1-3 = 675 gpm ea., CHWP 4; 5 = 180gpm ea.) Repeat to see 1st lag chiller stage off. Repeat to see lead chiller stage off.	2nd Lag Chiller Staging OFF* Observe that when the total SCHW gpm has reduced to be <= the sum of the first two selected SCHW pumps, that the second lag SCHW pump shuts OFF. Primary CHW flow > secondary flow by _____ [_____] gpm. Time: [_____]. After 20 minutes, 2nd lag chiller and pumps should stop. Time when 2nd lag chiller stops = [_____]. Cooling tower fans shut down as expected: Main fan—pony motor--all OFF. First Lag Chiller Staging OFF* Observe that when the total SCHW gpm has reduced to be <= the lead SCHW pump for 10 minutes, that the first lag SCHW pump shuts OFF. Primary CHW flow > secondary flow by _____ gpm. Time: [_____]. After 20 minutes, 1st lag chiller and pumps should stop. Time when 1st lag chiller stops = [_____]. Cooling tower fans shut down as expected: Main fan--pony motor--all OFF. Lead Chiller Staging OFF* When all CCVs are < 15% open for 10 min. and after an additional 20 min. delay, lead chiller and all pumps should shut down. *No no-flow alarms should be generated during normal staging down.		
9 Seq 41-42	Specs 15682 3.3.; 15683 3.2	CDP 6; 7 and HE-1. Continuing with the last sequence of staging OFF the chillers: When the lead chiller shuts down CDP 6 or 7 still function.	Observe that the CDP-6 or 7 and CDP 8 or 9 still run and that the CDWT remains the constant.		

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
10 Seq 41	Specs 15755 3.3	Heat Exchanger HE-1. With the chillers off, generate a significant load call from ACU's served by HE-1. Take temp. readings of entering and exiting HE water.	Observe the temperature differences of the CDW and the ACU supply water across the heat exchanger. Verify that they are in line with the manufacturer's specs. Attach specs. Water Temps (F) CDW In CDW Out ACU In ACU Out [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____] [_____]		
11 Seq 33-35	Specs 15682 3.3.; 15683 3.2	Variable Speed Drive (VFD) on CHWP-6. (Note: VFD operation with multiple SCHW pumps operating is tested in procedure 3 and 6. a. Perform an amps vs hz test to establish how low the pump speed can safely go by: putting the chiller in operation at its lowest setting: ie, one CCV 15% open. Manually successively lower the pump speed starting at 60 Hz and record the motor amps at each step. When the amps begin to increase, the lowest safe motor speed has been found.	CHWP-6 CHWP-7 CHWP-8 Amps Amps Amps 60 50 40 35 30 25 20 15 10 Motor manufacturer's recommended or site tested low speed limit = [_____ Hz].		

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
11 cont. Seq 33-35	Specs 15682 3.3.; 15683 3.2	1. Carefully go over prefunctional checklist and programming record and identify anomalies. Record the low limits.	1. Low limit setting in drive: [_____Hz, rpm = _____% of maximum]. Provide reasons for low limit not being at motor mfr's low limit. List any anomalies noticed in programming:		
		2. With only chiller associated with CHWP-6 running and other chillers manually OFF, reduce all cooling load or manually lower pump and remote differential pressure setpoints. See how low VFD will go.	2. Lowest speed drive will go: [_____Hz, rpm]. Is this within 3 Hz of the low limit setting (or within a range equal to 5% of maximum speed)? Is pump and remote dP SP maintained without hunting?		
		3. Call for moderate cooling or increase differential pressure setpoints.	3. Does VFD motor ramp up accordingly in a reasonable time? Is pump and remote dP SPt maintained without hunting?		
		4. Call for maximum cooling or increase differential pressure setpoints (keeping only 1 chiller ON).	4. Does VFD motor ramp to full speed in a reasonable time? Is pump and remote dP SPt maintained without hunting?		

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
12 Seq 33-35	Specs 15682 3.3.; 15683 3.2	Variable Speed Drive (VFD) on CHWP-7. (Note: VFD operation with multiple SCHW pumps operating is tested in procedure 3 and 6. Perform and record amps vs Hz test in Procedure 11. 1. Carefully go over prefunctional checklist and programming record and identify anomalies. Record the low limits. 2. With only chiller associated with CHWP-7 running and other chillers manually OFF, reduce all cooling load or manually lower pump and remote differential pressure setpoints. See how low VFD will go. 3. Call for moderate cooling or increase differential pressure setpoints. 4. Call for maximum cooling or increase differential pressure setpoints (keeping only 1 chiller ON).	Motor manufacturer's recommended or site tested low speed limit = [_____ Hz]. 1. Low limit setting in drive: [_____Hz, rpm = _____% of maximum]. Provide reasons for low limit not being at motor mfr's low limit. List any anomalies noticed in programming: 2. Lowest speed drive will go: [_____Hz, rpm]. Is this within 3 Hz of the low limit setting (or within a range equal to 5% of maximum speed)? Is pump and remote dP SP maintained without hunting? 3. Does VFD motor ramp up accordingly in a reasonable time? Is pump and remote dP SPt maintained without hunting? 4. Does VFD motor ramp to full speed in a reasonable time? Is pump and remote dP SPt maintained without hunting?		

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
13 Seq 33-35	Specs 15682 3.3.; 15683 3.2	Variable Speed Drive (VFD) on CHWP-8. (Note: VFD operation with multiple SCHW pumps operating is tested in procedure T-3 and T-6. Perform and record amps vs Hz test in Procedure 11. 1. Carefully go over prefunctional checklist and programming record and identify anomalies. Record the low limits. 2. With only chiller associated with CHWP-8 running and other chillers manually OFF, reduce all cooling load or manually lower pump and remote differential pressure setpoints. See how low VFD will go. 3. Call for moderate cooling or increase differential pressure setpoints. 4. Call for maximum cooling or increase differential pressure setpoints (keeping only 1 chiller ON).	Motor manufacturer's recommended or site tested low speed limit = [_____ Hz]. 1. Low limit setting in drive: [_____Hz, rpm = _____% of maximum]. Provide reasons for low limit not being at motor mfr's low limit. List any anomalies noticed in programming: 2. Lowest speed drive will go: [_____Hz, rpm]. Is this within 3 Hz of the low limit setting (or within a range equal to 5% of maximum speed)? Is SP maintained without hunting? 3. Does VFD motor ramp up accordingly in a reasonable time? Is SP SPt maintained without hunting? 4. Does VFD motor ramp to full speed in a reasonable time? Is SP SPt maintained without hunting?		
14 Seq 8, 21-24; 32-35	Specs 15682 3.3.; 15683 3.2	General Staging. By Monitoring: For each chiller, trend the status of CH, PCHWP, SCHWP, CDWP, CT pony fan, CT main fan, OSAT, CHWST, ECDWT, primary gpm, secondary gpm, VFD rpm for each pump. (Start all points simultaneously, 5 min. time step for 3 days, including weekend during a period of significant cooling. Provide text file (ASCII).	Observe that there are no anomalies in operation, comparing to the specified sequences and staging. This is not a detailed "to the minute" staging verification, which was done manually above. Attach representative graphs or columnar data and explanatory analysis to this test report.		

MISC. CHILLER SYSTEM FUNCTIONS					
15 Seq 13	Specs 15682 3.3.; 15683 3.2	Demand Limiting. With one chiller running, enable the demand limiting routine and temporarily reduce the limiting delay from 1 hour to 20 minutes. Lower the kW limit to be equal to 90% of the lead chiller design kW. Initiate sufficient load to call for two chillers.	Observe that CCV's run to 100% open, indicating a call for cooling and an unsatisfied condition. Note that the lag chiller is called for, but does not turn on until the programmed delay is over.		
16 Seq 1	Specs 15682 3.3.; 15683 3.2	OSAT Lockout. With chiller(s) running in auto, overwrite OSAT sensor to be 55F.	Observe a shutdown of the chillers, including secondary CHW pumps..		
17 Seq 1	Specs 15682 3.3.; 15683 3.2	OSAT Lockout. By Monitoring. During chilled water pressure control monitoring:	Observe a shutdown of the chillers, including secondary CHW pumps, whenever the OSAT is less than 55F Attach representative graphs or columnar data and explanatory analysis to this test report.		
18 Seq 19	Specs 15682 3.3.; 15683 3.2	Primary CHW Pump Failure, CH-1; 2. With only the lead chiller running (in auto), manually shut off the lead primary CHW pump .	Operating chiller should stop and go into failure alarm. The lag chiller then becomes the lead chiller and should start.		
19 Seq 19	Specs 15682 3.3.; 15683 3.2	Primary CHW Pump Failure, CH-3. With the chiller running in auto, manually shut off the primary CHW pump. .	An alarm should register and the standby primary CHW pump should start automatically.		
20 Seq 22	Specs 15682 3.3.; 15683 3.2	CD Pump Failure, CH-1; 2. With only the lead chiller running (in auto), manually shut off the CD pump.	Operating chiller should stop and go into failure alarm. The lag chiller then becomes the lead chiller and should start.		
21 Seq 22	Specs 15682 3.3.; 15683 3.2	CD Pump Failure, CH-3. With the chiller running in auto, manually shut off the primary CD pump. .	An alarm should register and the standby CD pump should start automatically.		
22 Seq 37	Specs 15682 3.3.; 15683 3.2	Secondary CHWP Failure. With at least one chiller and pumps in auto, and running, shut off variable speed drive to lead SCHWP.	Observe that lag or standby SCHWP starts.		

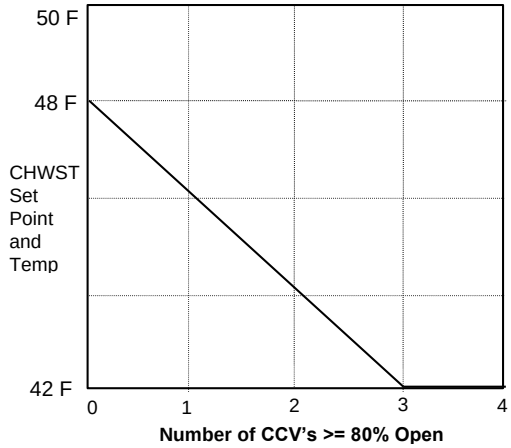
23	Specs 15682 3.3.; 15683 3.2	Chiller Standby 1. With chillers manually OFF, turn 1st lag chiller to Auto and cause a call for the chillers.	Lead primary CHWP pump should start and orig. lead chiller should try and start, but fail. CHWP should shut off. After ____ [_____] minutes DDC should start the lag CHW pump, etc. and 1st lag chiller and function as lead. (shorten delays for test, if desired)		
24	Specs 15682 3.3.; 15683 3.2	Chiller Standby 2. Repeat above to test 2nd lag chiller as lead.	First two chillers remain off. 2nd lag chiller starts.		
25 Seq 21	Specs 15682 3.3.; 15683 3.2	Manual Standby CDP- for CH-1 & 2. With chillers OFF, manually operate valves to allow standby CDP to function and assign as lead pump. Turn chillers to auto with CH-1 or 2 as lead. Initiate a call for the chillers.	Observe that standby CDP operates and that gpm is as per design, 1350 gpm [_____gmp].		
26 Seq 18	Specs 15682 3.3.; 15683 3.2	Manual Standby PCHWP- for CH-1 & 2. With chillers OFF, manually operate valves to allow standby primary CHWP to function and assign it as lead pump. Turn chillers to auto with CH-1 or 2 as lead. Initiate a call for the chillers.	Observe that standby PCHWP operates as lead and that gpm is as per design, 675 gpm [_____gpm].		
27 Seq 43	Specs 15682 3.3.; 15683 3.2	CDP 6; 7 Failure Lead = CDP-____ (6 or 7) With system in auto and running, manually shut down lead pump. CDP 8; 9 Failure Lead = CDP-____ (8 or 9) With system in auto and running, manually shut down lead pump.	Observe that an alarm is registered and that the lag pump starts. Observe that an alarm is registered and that the lag pump starts.		

28 Seq 6;7	Specs 15682 3.3.; 15683 3.2	CHWS Reset. With one or more chillers running in auto, change conditions to provide data points near both ends of the line and one near the middle of the chart below. A. Mark current SPt conditions on chart with a star and CHWSTemp with a dot. B. Increase cooling demand by lowering space setpoints 8°F in all zones or by manually opening preheat coil valves. Observe that the system pipe pressure is not reset upward until the CHWST is at its maximum. In BAS, observe CCV's opening for AHU 1, 2, 3; 4 and CHWS setpoint lowering. Mark SPt values on chart with a star. Observe that the CHWST meets setpoint w/o excessive hunting. Mark CHWST values on chart with a dot.	Current CHWST setpoint: _____ A. Values in middle of chart; near line. B. DP pressure setpoint does not increase until CHWST is at its maximum. [_____] Values in the bottom right of chart; near the line.		
28 cont. Seq 6;7	Specs 15682 3.3.; 15683 3.2	CHWS Reset cont. C. Remove cooling demand by raising space setpoints 8°F above normal in all zones or by other suitable method. Observe secondary pump speed lowering and that CHWT setpoint doesn't change until pumps are at their minimum. Observe CCV's closing for AHU 1, 2, 3; 4 and CHWS setpoint raising. Mark SPt values on chart with a star. Observe that the CHWST meets setpoint w/o excessive hunting. Mark CHWT values on chart with a dot. D. In condition B, Overwrite RA RH to be 53%.	C. CHWST setpoint does not raise until all secondary pumps are at min. speed. [_____] Values in the top left of chart; near the line. D. Observe that the SPt does not change further.		

CHWST Reset Chart.

For each observation, mark CHWS temp with a dot and the current CHWS temperature setpoint with a star. After system settles, all values should fall within 1F of the line and the actual temp. should be within 1F of setpoint.

Note how many minutes after the call for a change was made, that readings were recorded.



29 Seq 6	Specs 15682 3.3.; 15683 3.2	CHWS Temperature Reset. By Monitoring: Trend CHWST setpoint, CHWS temperature, CCV positions for AHU 1, 2, 3; 4. (Start all points simultaneously, 5 min. time step for 5 days, including weekend. Provide text file (ASCII).	Make similar observations as for the manual test. Observe that the CHWS SPt changes as expected and CHWST meets setpoint w/o excessive hunting. Attach representative graphs or columnar data and explanatory analysis to this test report.		
30 Seq 33	Specs 15682 3.3.; 15683 3.2	Chilled Water Pressure Control. Setpoint is to have one CCV 90% open. With one or more chillers running in auto and with all CCV's less than 90% open. Increase the call for cooling by lowering DAT or space temperature setpoint. Increase the call for cooling by lowering DAT setpoint or space temperature setpoint. Significantly increase the call for cooling by lowering DAT or space temperature setpoint. Decrease the call for cooling so that no CCVs are more than 90% open.	Beginning pump dP SPt: [_____] Beginning remote dP SPt:[_____] Observe that that when the first CCV opens more than 90% [_____%] the remote dP SPt increases relative to how much greater than 90% open the CCV is. New remote dP SPt = [_____] and new dP = [_____]. Observe that the pump dP SPt also increases. New pump dP SPt = [_____] and new dP = [_____]. Observe that the SCHW pump speed increases to meet the pump dP SPt and only one CCV at 90% open. Observe that after a forced 5 min. delay, if the most open CCV is less than 90% open [_____], the remote and pump dP SPt's decrease and SCHW pump speed decreases. Observe that as the load is increased substantially, that dP SPt's increase to try and maintain only one CCV greater than 90% open. More than one CCV may be open more than 90% at the same time, but not for more than 5-10 minutes. Observe that the dP SPt lowers from current [_____] to [_____] until there is one CCV 90% open. Observe that the CHWST setpoint does not raise until the dP SPt is at its minimum.		

31 Seq 33	Specs 15682 3.3.; 15683 3.2	Chilled Water Pressure Control. By Monitoring. Trend all CCV positions, pump discharge differential pressure and setpoint, remote pressure and setpoint, VFD rpm on each CHW pump; OSAT. Trend during season of moderate to significant cooling for 3 days at a sampling rate of every 5 minutes; 24hrs per day with output in ASCII file columnar format.	Observe that there is generally only one CCV more than 90% open. At times, not lasting more than about 10 minutes, there could be more than one CCV more than 90% open. The goal is to have one, and only one, CCV 90% open at all times. Attach representative graphs or columnar data and explanatory analysis to this test report.		
32 Seq 5	Specs 15682 3.3.; 15683 3.2	System Stabilization. Analyze CHW reset and pressure control monitoring data.	Verify that the CHWS temperature is stable and maintains the CHWS SPt within 0.5F over a range of conditions and days.		
33 Seq 40	Specs 15682 3.3.; 15683 3.2	Secondary Pumps for Freeze Protection. With chillers in auto, but not running, manually start smoke exhaust system EF-10 and overwrite OSAT to be 38F.	Observe that SCHW pumps operate normally. (EF-10-associated AHU CCV's should also be open).		
34 Seq 5	Specs 15683 3.2	CH-3 (Reciprocating) Staging. By Monitoring. Temporarily program the BAS to readout and trend the stage of CH-3. With CH-3 as lead chiller in auto, call for chillers using a suitable method. After CH-3 is fully loaded, remove all load. During the above, trend the CH-3 stage, the CHWST and the CHWST Spt at 2 min. intervals for 1 hour or until chiller is fully loaded and then unloads to stop. Provide tabular or graphical documentation.	Loading: The trends should follow the 8 staging sequences of stage vs CHWST offset from setpoint (accounting for programmed delays), etc. as per the programmed sequences. Unloading: The trends should follow the staging sequences of stage vs CHWST offset from setpoint (accounting for programmed delays), etc. as per the programmed sequences. Attach representative graphs or columnar data and explanatory analysis to this test report.		
35	--	For all chiller and cooling tower components, review current setpoints and sequences with specifications and control drawings. Submit approved differences to be incorporated in asbuilts.	Setpoints and sequences are the same as original specs. OR Differences submitted for asbuilts.		
CHILLER SAFETY CONTROLS					
36 Seq 2; 3	Specs 15682 3.3.; 15683 3.2	CHW Flow Switch CH-1. If PCHW pump is wired in series with proof of flow switch, jumper pump out of this loop. With chillers manually off, but under conditions that will call for chillers, manually turn off PCHW pump. Turn Chiller 1 to auto.	Observe that chiller won't start because of no CHW flow and that an alarm is generated.		

37 Seq 2; 3	Specs 15682 3.3.; 15683 3.2	CHW Flow Switch CH-2. If PCHW pump is wired in series with proof of flow switch, jumper pump out of this loop. With chillers manually off, but under conditions that will call for chillers, manually turn off PCHW pump. Turn Chiller 2 to auto.	Observe that chiller won't start because of no CHW flow and that an alarm is generated.		
38 Seq 2; 3	Specs 15682 3.3.; 15683 3.2	CHW Flow Switch CH-3. If PCHW pump is wired in series with proof of flow switch, jumper pump out of this loop. With chillers manually off, but under conditions that will call for chillers, manually turn off PCHW pump. Turn Chiller 3 to auto.	Observe that chiller won't start because of no CHW flow and that an alarm is generated.		
39 McQuay O&M	Specs 15682 3.3.; 15683 3.2	Low evap. refrigerant temp/pressure TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
40 McQuay O&M	Specs 15682 3.3.; 15683 3.2	High condenser pressure TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
41 McQuay O&M	Specs 15682 3.3.; 15683 3.2	High motor winding temperature TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
42 McQuay O&M	Specs 15682 3.3.; 15683 3.2	Low differential oil pressure TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
43 McQuay O&M	Specs 15682 3.3.; 15683 3.2	Low differential oil pressure TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		

44 McQuay O&M	Specs 15682 3.3.; 15683 3.2	Loss of any electrical power phase TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
45 McQuay O&M	Specs 15682 3.3.; 15683 3.2	High oil temperataure TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
46 McQuay O&M	Specs 15682 3.3.; 15683 3.2	High bearing temperature TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
47 McQuay O&M	Specs 15682 3.3.; 15683 3.2	Ground fault protection TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
48	Specs 15682 3.3.; 15683 3.2	Interlocking of chillers and pumps This is demonstrated in procedures above (not the safeties).			
OTHER COOLING TOWER FUNCTIONS					
49 Seq 28	Specs 15682 3.3.; 15710 2.2	CT-1 Fan Failure Alarm. With CT running, manually shut off either of its fan motors.	Observe that an alarm is registered. Lag CT comes on line automatically??? Manually???		
50 Seq 28	Specs 15682 3.3.; 15710 2.2	CT-2 Fan Failure Alarm. With CT running, manually shut off either of its fan motors.	Observe that an alarm is registered. Lag CT comes on line automatically??? Manually???		
51 Seq 28	Specs 15682 3.3.; 15710 2.2	CT-3 Fan Failure Alarm. With CT running, manually shut off either of its fan motors.	Observe that an alarm is registered. Lag CT comes on line automatically??? Manually???		

52 Seq 29	Specs 15682 3.3.; 15710 2.2	Jump the vibration sensor to simulate a vibration alarm. CT-1: CT-2: CT-3:	Observe that an alarm is registered and that the CT fan shuts off. Lag CT comes on line automatically??? Manually???		
53 Seq 25	Specs 15682 3.3.; 15710 2.2	CT High Water Alarm. Plug sump overflow and override the makeup valve, causing the CT sump to over-fill.	Observe that a high water limit alarm is registered.		
54 Seq 27	Specs 15682 3.3.; 15710 2.2	CT Low Water Alarm and Makeup Override the makeup valve, causing the CT sump to not-fill. Drain the sump below the alarm level. Return makeup valve to auto.	Observe that a low water limit alarm is registered. Observe makeup valve open slowly and fill sump until proper level; then close.		
55 Seq 30	Specs 15682 3.3.; 15710 2.2	Winter Operation. During weather with OSAT below 25F, inspect CT.	Observe the functioning of the heat tape, verify that the sump temperature is above setpoint, verify that freezing water on the media is not excessive. Be sure that the fans do not come on when water is going over the tower (as only 60F need be achieved).		
56 Seq 26	Specs 15682 3.3.; 15710 2.2	CT Sump Heaters. (if not documented during startup) Schedule: (setpoint = 45F) ON (F) OFF (F) Stage 1 45 43 Stage 2 47 45 Starting with sump heaters not running, overwrite sump temperature to be equal to stage 1 SPt. Then, lower to stage 2 SPt. Then raise to 1 F above 2nd stage OFF SPt. Then lower to 1st stage OFF SPt. Repeat for each CT.	Actual: ON (F) OFF (F) CT-1 Stage 1 [_____] [_____] Stage 2 [_____] [_____] CT-2 Stage 1 [_____] [_____] Stage 2 [_____] [_____] CT-3 Stage 1 [_____] [_____] Stage 2 [_____] [_____]		

REPEAT PROCEDURES 1-8 WITH CHILLER 2 AS LEAD:

CHILLER SYSTEM STARTUP AND STAGING (2nd chiller as lead)

1b Seq 1-4, 16, 20-23; 32		Startup Sequence. Lead = CH-____. (This is not the initial startup by factory reps). With chiller system off, with schedule allowing chillers ON and OSAT >56F, turn chillers and pumps to auto. Turn on AHUs and cause a call for cooling sufficient to call for chillers (manually open preheat coil valve, lower space temperature SPt, etc. A call for the chillers will be made when any AHU fan is ON and its CCV is => 15% open for 10minutes. Vanes: Cooling Tower: Specified Sequences: ECDWT Fan Spd ON (F) OFF (F) OFF <69 --- (bypass valve modulating) *Low 69 75 *High 73 69 * Bypass valve should be closed. Eight minute delay between stages. Maintain chiller load between 10-15% for 30 minutes.	Observe that the lead primary CHW pump does not turn ON until a CCV on an ON AHU is => 15% [_____%] open for 10 min. [_____]. Observe lead secondary CHW pump start when a CCV is 15% [_____] open for 10 [_____] minutes. Observe CHW primary and secondary pumps turning on, then the oil pump; then the CD pump (30-60s delay ea.) Observe that secondary pumps start at minimum RPM and slowly ramp up. Starting RPM = [_____]. Observe the lead chiller starting. Observe that the vanes start closed and begin to open. (max spd = 0-full open in ~3 min. and closed in ~1 minute) OSAT = [_____F]. Observe that when the lead chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPt of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps during lead chiller operation only: [_____], [_____], [_____], [_____], [_____]. Record of Observed Sequences: ECDWT Delay Fan Spd ON (F) OFF (F) (min) OFF [_____] --- (bypass valve modulating) Low [_____] [_____] [_____] High [_____] [_____] [_____] Observe that there is no surging or abnormal vibration.		

2b Seq 8		1st Lag Chiller Staging ON. Staging sequence: CH-___ -->CH-___ -->CH-___ With chillers in auto, and loaded such that only lead chiller is running, lower space setpoints so CCVs open. Wait ~10 minutes. Record time that primary flow and secondary flow become equal. Wait 20 minutes.	Total primary flow = [_____gpm]. Secondary CHW flow => primary CHW flow = [_____gpm] and lead chiller is at least 95% loaded (by % of rated current), [_____ amps]. Time: [_____]. After 20 minutes, 1st lag chiller should start (PCHWP - oil pump - CDP - chiller). Time when 1st lag chiller started = [_____]. Observe that the amps on both chillers are within 5% of each other.		
3b Seq 8; 32-34		1st Lag Secondary CHWP Staging ON. Continue increasing cooling load, if necessary, to cause CCVs to open further.	Observe that after total SCHW flow [_____gpm, _____rpm] > total design flow of ON SCHW pumps (765 gpm), and the SCHW pump dP drops 2 psi [_____] below SPt for 10 minutes, the first lag SCHWP turns ON. Observe that the 2 pumps' rpm are aprox. equal and at aprox. 50% (880 rpm), [CHWP-_____ rpm, CHWP- _____ rpm] and that total flow is just over previous gpm (765) [_____gpm], and that after ~ 2 minutes, pump dP is maintained at SPt _____ [_____] and remote dP is maintained at SPt _____ [_____].		
4b Seq 8; 21-24		1st Lag Cooling Tower Staging ON. During the preceding sequences:	OSAT = [_____F]. Observe that when the 1st lag chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPt of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps when both chillers are operating: [_____], [_____], [_____], [_____], [_____]. Record of Observed Sequences: ECDWT Delay Fan Spd ON (F) OFF (F) (min) OFF [_____] --- (bypass valve modulating) Low [_____] [_____] [_____] High [_____] [_____] [_____]		

5b Seq 8		2nd Lag Chiller Staging ON Cont. After second chiller starts, continue calling for more cooling to start third chiller.	Total primary flow = [_____gpm]. Observe until secondary CHW flow => primary CHW flow = [_____gpm] and both chillers are at least 95% loaded (by % of rated current), [_____amps]. Time: [_____]. After 20 minutes, 2nd lag chiller should start (PCHWP - oil pump - CDP - chiller). Time when 2nd lag chiller started = [_____]. Observe that the amps on all running chillers are within 5% of each other.		
6b Seq 8; 32-34		2nd Lag Secondary CHWP Staging ON Cont. Continue increasing cooling load, if necessary, to cause CCVs to open further.	Observe that after total SCHW flow [_____gpm, CHWP- _____rpm, CHWP-_____rpm] is greater than total design flow of ON SCHW pumps (1530 gpm), and the SCHW pump dP drops 2 psi [_____] below SPt [_____] for 10 minutes, the 2nd lag SCHWP turns ON. Observe that the 3 pumps' rpm are aprox. equal and at aprox. 67% (1170 rpm), [CHWP- _____ rpm, CHWP-_____ rpm, CHWP- _____ rpm] and that total flow is just over previous gpm (1530) [_____gpm], and that after ~ 2 minutes, pump dP is maintained at SPt _____ [_____] and remote dP is maintained at SPt _____ [_____].		
7b Seq 8; 21-24		2nd Lag Cooling Tower Staging ON. During the preceding sequences:	OSAT = [_____F]. Observe that when the 2nd lag chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPt of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps when all three chillers are operating: [_____], [_____], [_____], [_____], [_____]. Record of Observed Sequences: ECDWT Delay Fan Spd ON (F) OFF (F) (min) OFF [_____] --- (bypass valve modulating) Low [_____] [_____] [_____] High [_____] [_____] [_____]		

8b Seq 9; 10; 35		Chillers Staging OFF. Raise space setpoints so CCVs close, or shut off some or all AHU's. Wait ~10 minutes. Record time that primary flow exceeds secondary flow by capacity of last selected pump. Wait thru 20 min. delay. (CHWP 1-3 = 675 gpm ea., CHWP 4; 5 = 180gpm ea.) Repeat to see 1st lag chiller stage off. Repeat to see lead chiller stage off.	2nd Lag Chiller Staging OFF* Observe that when the total SCHW gpm has reduced to be <= the sum of the first two selected SCHW pumps for 10 minutes, that the second lag SCHW pump shuts OFF. Primary CHW flow > secondary flow by _____ [_____] gpm. Time: [_____]. After 20 minutes, 2nd lag chiller and pumps should stop. Time when 2nd lag chiller stops = [_____]. Cooling tower fans shut down as expected: Main fan--pony motor--all OFF. First Lag Chiller Staging OFF* Observe that when the total SCHW gpm has reduced to be <= the lead SCHW pump for 10 minutes, that the first lag SCHW pump shuts OFF. Primary CHW flow > secondary flow by _____ gpm. Time: [_____]. After 20 minutes, 1st lag chiller and pumps should stop. Time when 1st lag chiller stops = [_____]. Cooling tower fans shut down as expected: Main fan--pony motor--all OFF. Lead Chiller Staging OFF* When all CCVs are < 15% open for 10 min. and after an additional 20 min. delay, lead chiller and all pumps should shut down. *No no-flow alarms should be generated during normal staging down.		
57	--	Return all changed control parameters and conditions to their pre-test values5	Check off in table of Section 2 above when completed		

SEQUENCES AND COMPONENTS NOT TESTED					
58		Vibration Isolators. Not tested.			
59		Capacity Testing Not tested.			
60		SCHW Pump End of Curve Safety. Not tested (from examining the pump curves and operating points, pumps are sufficiently oversized to make an end of curve event highly unlikely)			

MONITORING AND TREND LOGGING. Monitoring via BAS trend logs are required per test Procedures 10, 14, 17, 29, 31, 57. Trend logs all shall be provided in electronic continuous columnar spreadsheet compatible format. Trends all shall be provided in hard tabular format (continuous columnar with time in left column and at least four columns of point values in adjacent columns). All points for a given trend will begin at exactly the same time. Provide a key to all abbreviations. Attach representative graphs or columnar data and explanatory analysis to this test report.

**Abbreviations:

SCHW = secondary chilled water,
PCHW = primary chilled water.
dP = diff. pressure,
SPt = setpoint
CHWS = chilled water supply,
CT = cooling tower,
BAS = building automation system.

1. Sequences of operation attached to this test.

2. Mode or function ID being tested from testing requirements section of the project Specifications.

3. Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

4. Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, conrols contractor or vendor. Write “Via BAS” for verifications of device position from BAS readout or “Via obs” for actual observation or from test instrument reading.

5. Record permanently changed parameter values and submit changes to Owner.

6. Methods to False Load Chillers

    a. If OSAT is less than 75F, prevent economizer cool OSA from entering the building.

    b. Manually close the economizer OSA dampers, OR

    c. Lower the changeover economizer setpoint below the OSAT (if DB type), OR lastly

    d. Overwrite the OSAT value to be 80F or more so dampers won’t open.

    e. Use OSA preheat coils to heat incoming OSA.

    f. Enable the boiler by removing any lockouts, etc. Manually open the min. OSA preheat coil valve to preheat the OSA. Increase the min. OSA discharge temperature setpoint and the heating water supply temperature, as necessary.

    g. Lower the space temperature setpoint.

    h. Prior to the chiller test, manually preheat the building space temperature to 78F - 80F.

    i. Lower the chilled water supply temperature setpoint.

7. False Loading Cooling Towers

    a. False load the chiller (see above)

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

-- END OF TEST --

REPRESENTATIVE TEST

TEST 2 OF 3. TYPE: B - MODERATE

The following test is a sample of the detail and rigor of tests that will be used for this Project. The layout/format of the form used may not be similar.

Project: _____

FT-_____ AIR HANDLER UNIT AHU-_____

Including integral equipment: supply fans, exhaust fan and variable speed drives

Related Tests: _____

I. Participants:

Party	Participation
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Date of test _____

J. Prerequisite Checklist

1. The following have been started up and startup reports and conctruction checklists submitted and approved ready for testing:

   __ Duct system __ Chiller system

   __ Connected Terminal Units __ Boiler system

2. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed. _____ _____

   Controls SUBCONTRACTOR Signature or Verbal Date

3. __ Vibration control report approved (if required).

4. __ Test and balance (TAB) completed and approved for the hydronic systems and terminal units connected.

5. __ All A/E punchlist items for this equipment corrected.

6. __ These functional test procedures reviewed and approved by installing CONTRACTOR.

7. __ Safeties and operating ranges reviewed.

8. __ Test requirements and sequences of operation attached.

9. __ Schedules and setpoints attached.

10. __ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)

11. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.

12. __ Misc. tools needed: __two-way radios (general c.), __original calibration temperature probe (controls c.), pressure gages for evaporator dP, only if verifying cooling coil performance (mechanical c.), temperature probe with 6 ft wire or data logger for air and insertion into water P/T (commissioner), amp meter for pump amps (commissioner), wet bulb temperature probe on 6 ft wire if verifying cooling coil performance (commissioner).

13. __ BAS Program Review. Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.

14. __ Packaged Control Program Review. Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences. Primary setpoints are documented in writing.

15. __ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, CTC. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Duct static pressure set-point		
High discharge SP alarm	4.5”	
Supply air reset schedule		
Low ambient lockout		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Cooling coil low temp alarm setpoint	35F	
Space temp. setpoint		
Bldg. static pressure set-point		

K. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

“In calibration” means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, packaged control panel or building auto-

mation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK1	1st Gage or Pkg & BAS Values	Instru. Meas'd Value	Final Gage or Pkg & BAS Values	Pass Y/N?
SAT		Pkg: BAS:		Pkg: BAS:	
RAT		Pkg: BAS:		Pkg: BAS:	
MAT		Pkg: BAS:		Pkg: BAS:	
OSAT		Pkg: BAS:		Pkg: BAS:	
Disch. SP		Pkg: BAS:		Pkg: BAS:	
Enthalpy		Pkg:		Pkg:	

1Sensor location is appropriate and away from causes of erratic operation.

L. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during construction checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	Procedure/State	1st BAS Value	Site Observation	Final BAS Reading	Pass Y/N
VFD* on supply fan	1. Min.: _____%				
(read in BAS and at VFD)	2. Max.: _____%				
VFD* on return fan	1. Min.: _____%				
(read in BAS and at VFD)	2. Max.: _____%				
Exhaust fan damper position	1. Closed				
	2. Full open				
Return damper position	1. Closed				
	2. Full open				
Min. OSA damper position	1. Closed				
	2. Full open				
Economizer damper position**	1. Closed				

Device or Actuator & Location	Procedure/State	1st BAS Value	Site Observation	Final BAS Reading	Pass Y/N
	2. Full open				
Cooling coil valve position	1. Closed				
	2. Full open				
Heating coil valve position	1. Closed				
	2. Full open				

*Vanes or VFD: Procedure 1. Lower the controlling static pressure setpoint (duct or discharge) to be 1/4 of its current value. Verify that the vanes are shut, or fan speed is at minimum for VFD and packaged controller reads the same. Return the static pressure setpoint to normal. Procedure 2. Lower the space temperature setpoint to be 20 degrees F below space temp. and cause TU dampers to go to full cooling. Raise the static pressure setpoint as necessary to cause the setpoint to not be met. Verify that the inlet vanes are fully open or the fan speed is at its max. and verify that the packaged controller reads the same. Return all to normal.

**OSA Damper. Procedure 1. Change minimum OSA damper position setting to 0%. Change economizing parameter as necessary to cause damper to go to minimum. Verify that the damper is shut. Change the minimum OSA damper position setting to 100%. Verify that the damper is fully open. Return all to normal.

M. Verification of Miscellaneous Construction Checks.

Misc. site checks of the construction checklist and startup reports completed successfully.
Pass? Y / N _____

1. Verify that the location of the duct static pressure sensor is located at least 2/3 down the duct and 5 duct diameters upstream and 10 diameters downstream from duct elbows, transitions or takeoffs. _____ Y/N.

2. Verify that the cooling coil is counter-flow (exiting return pipe is upstream). _____Y/N.

3. Verify the following VFD settings for each VFD:

___OK. Verify that the VFD hp rating matches the fan (SF 100 hp, RF 50 hp).

___OK Check lower limits: Manufacturer's recommendation: _____. Actual setting: [SF_____, RF _____] (should be 10% or 6 Hz for forward curved fans and 35% or 21 Hz for air-foil fans, unless manufacturer has directed otherwise.

___OK Check high limit setting: Hz: [SF_____, RF_____] (should be 60-65 Hz). Current: [SF_____, RF_____] (should be 100-110%).

___OK Verify that the acceleration and deceleration times are between 20-100 seconds. Actual settings, acceleration: [SF_____, RF____] deceleration: [SF____, RF____].

4. ___OK Verify that any special filters required in the system are installed per spec.

General Conditions of Test:
The building TUs, chiller and boilers will be in normal occupied mode.

N. Functional Testing Record

Proced No.	Sequence ID2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1.		Off Condition. Turn the unit to OFF condition. VFD in auto.	Exhaust [___], min. OSA [____] and Economizer [____] dampers closed, RA dampers open [___]; associated exhaust fan(s) (EF-3 for ASU-1 and EF-4 for ASU-2) are OFF [____].	
2.	1; 2	Startup. Turn unit to auto, with schedule showing occupied.	Observe the SF and RF start slowly ramping up. [_____]. Once started associated EF starts [___]. Min. OSA damper opens (since there is no warm-up mode) [____]. Observe that the duct static pressure doesn't initially overshoot setpoint (_____"WC) by more than 20% [overshoot _____"WC = _____%]. Observe unit maintaining the duct static pressure setpoint [_____].	
3.	3	Volume Capacity & Duct Static Pressure Control. With all settings at normal. a. Record duct static pressure. b. Command all TU dampers to minimum (via direct command or by raising the space temp. setpoint 20F above space temp).	a. Current duct static pressure = [_____]. Current fan speed [_____]. b. VFD should cause fan to ramp down. Wait until conditions stabilize. Record SF speed [_____] and duct SP [_____]. Static pressure should remain at setpoint [_____]. Is VFD taking fan down low enough, but not lower than 10 Hz? [_____]. Exhaust fan should be running at (SF cfm – min OSA cfm (_____)) = (_____). Actual = [_____].	
4.	3	Volume Capacity & Duct Static Pressure Control—cont. Command all TU dampers to max. cooling (via direct command or by lowering the space temperature setpoint 20F below space temp.). Return TUs to normal.	Fan should ramp up to near full speed (or speed that the balancer reported to be max. needed (_____). Duct static pressure should remain at setpoint [_____]. Exhaust fan should be running at (SF cfm – min OSA cfm (_____)) = (_____). Actual = [_____].	
5.	6	Economizer Damper Control. a. If not already open, cause the economizer dampers to open some, by lowering DAT setpoint or overwriting DAT (describe _____. Record MAT _____, DAT _____, DAT SPt _____. With all other components in auto and normal mode overwrite the OSAT (_____) to be 2F greater than the RAT (_____). b. Overwrite the OSAT to be 3F below the RAT (__ - 3 = ____F)	a. Observe the economizer dampers close [_____] (but min. OSA damper remains open [_____]. b. Observe the economizer damper modu-	

Proced No.	Sequence ID2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
			late open [_____].	
6.	6	Mixed Air Temperature Limit Control. Continuing with the last procedure, with the economizer damper to open, overwrite the MAT sensor to read 50F and the OSAT to be 40F. Release all points when done.	Observe the economizer dampers close [_____] and then for the heating coil valve open [_____] as the system tries to maintain a minimum MAT of 53F.	
7.	6	DAT Reset. a. With all systems in auto, make sure all polled zones are within 4F of space setpoint. Record the zone farthest above its setpoint (_____). b. Overwrite that zone space temp to be 5F above its setpoint. Record the DAT setpoint. c. Overwrite a polled zone space temp to be 3F below its setpoint. DAT Reset Schedule Worst Zone (1) — DA Setpt +4F — 55F -2F — 68F (1) Farthest zone above its setpoint	a. Current DAT setpoint [_____]. b. Setpoint goes to 55F [_____]. DAT meets 55F without excessive hunting. c. Setpoint goes to 68F [_____]. DAT meets 68F without excessive hunting. CCV should close [_____].	
8.	++	Variable Speed Drives. a. Auto reset: Shut off power feeding VFD. Restore power. b. Manual. Change VFD to manual mode. c. Bypass. Change the VFD to bypass mode. (This may cause the fan to go to full speed).	a. Verify that VFD resets automatically [SF OK ___,. RF OK ____]. b. Verify that the VFD can manually ramp fan speed. [SF___, RF___] c. Verify that the fan still operates [SF____, RF_____]. Indicate speeds [SF_____, RF_____].	
9.	1	Emergency Shutdown—High Discharge Static Lower the ASU high discharge static setpoint (_____) to be 0.1 inch lower than the current discharge static pressure. Return setpoint to normal.	ASU should shut down [_____]..	
10.	1	Emergency Shutdown—Low Coil Alarm Raise the low coil alarm from 35F to be 1F above the current coil temperature of _____. Return the setpoint to original.	Observe a BAS alarm [_____] and the unit shut down [_____]. Both OSA dampers will close [_____] and the CCV [_____] and HCV [_____] will open and the chiller pump [_____] and heating water pump [_____] will start, if not ON.	

Proced No.	Sequence ID2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
11.	1	Emergency Shutdown—Fire Alarm Initiate a fire alarm.	Observe a BAS alarm and the unit shut down. (This may be done during the fire alarm test.)	
12.	1	Emergency Shutdown—Fire/Smoke Damper Initiate a fire/smoke damper to alarm and close (select one far from the ASU).	Observe a BAS alarm and the unit shut down. (This may be done during the fire alarm test.)	
13.	6, ++	Cooling Coil Leak-by Calibrate two water temperature sensors to within 0.2°F of each other. Fan may be ON or OFF. Pump must be running. Insert sensors into P/Ts on supply and return side of 3-way CCV, (supply side must be in moving water). Command coil valve to closed. After 10 minutes observe water delta T across coil and valve. If it is not greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.	Initial 5 min. 10 min. 15 min. Supply Return ____ _____ _____ Difference-→	
14.	6. ++	Heating Coil Leak-by Calibrate two water temperature sensors to within 0.2°F of each other. Fan may be ON or OFF. Pump must be running. Insert sensors into P/Ts on supply and return side of 3-way HCV, (supply side must be in moving water). Command coil valve to closed. After 10 minutes observe water delta T across coil and valve. If it is not greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.	Initial 5 min. 10 min. 15 min. Supply Return ____ _____ _____ Difference-→	
15.	++	Cooling Coil Capacity. This is an optional test. If the balance report clearly indicates that pressure drops across the coil meet spec, so as to show that the coil is not clogged in any way, this procedure is not necessary. Disposition: _____ Insert a thermometer in a representative location between the HC and CC. Fix the RA and Economizer Dampers. Measure the wetbulb temperature between coils (_____). Command the HCV open until the thermometer stabilizes at the CC design of 78.5F. Open CCV to 100%. Ensure only one	Coil: Leaving air temp.: Average of 4 temperature sensors: [_____] (design is 56F) Entering air temp: [_____] (design is 78.5) Entering water temp: [_____] (design is 42F) Leaving water temp: [_____] (design is 56F) This is a crude test, but temps should be close	

Proced No.	Sequence ID2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
		CWP is running. Record water pressure drop across pump and chiller evaporator and determine flow from evap. Vs gpm from manufacturer's chart and from pump curve [gpm = _____]. Design is 367 gpm. Adjust the fan VFD until the fan is supplying 60,000 cfm (design). Command the chilled water setpoint to be 42F. Wait until stabilized. Release all points when done.	to design conditions.	
16.	3	TREND LOG 1 Volume Capacity Control Trend the duct static pressure setpoint, duct static pressure, OSAT, SF Hz, RF Hz, SF cfm, RF cfm, for 2 days in 2 minute intervals, with all systems in normal mode. See Monitoring section at the end of this test.	Verify that the VFD is not hunting excessively in trying to maintain the static pressure setpoint (must maintain setpoint +/-10% of setpoint value). If there is not a wide enough range of fan speeds logged, repeat the trend with some simulated load conditions being applied. Verify that the RF is tracking the SF accurately.	
17.	6	TREND LOG 2. Warm Weather Temperature Control During weather greater than 55F, trend the OSAT, MAT, DAT, DAT setpoint, CCT, RAT, HCV position, CCV position, economizer, min. OSA, exhaust and return air damper positions, SF speed and temp. of polled zone farthest from its setpoint at 5 min. intervals for 2 days.	Observe that the dampers and valves modulate properly to maintain the DAT setpoint, including: The HCV is never open when the CCV is [_____]. Economizer damper and HCV are never open together [_____]. The economizer and return air dampers operate inversely together and the exhaust damper works inversely with the return air damper [_____]. That the sequence upon reduced cooling load is: close CCV, close economizer damper, open HCV until the MAT is 53F. Verify the reverse during an increase in cooling load [_____]. Observe that when the OSAT is > RAT, the economizer dampers are closed and that the min. OSA damper is always open [_____]. Verify that DAT is maintained within +/- 1.5F of setpoint, without hunting.[_____] and that the DAT is being reset according to the schedule [_____].	

Proced No.	Sequence ID2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
18.	6	TREND LOG 3. Cold Weather Temperature Control. During weather less than 40F, trend the OSAT, MAT, DAT, DAT setpoint, CCT, RAT, HCV position, CCV position, economizer, min. OSA, exhaust and return air damper positions, SF speed and temp. of polled zone farthest from its setpoint at 5 min. intervals for 2 days.	Observe that the dampers and valves modulate properly to maintain the DAT setpoint, including: The HCV is never open when the CCV is [_____]. Economizer damper and HCV are never open together [_____]. The economizer and return air dampers operate inversely together and the exhaust damper works inversely with the return air damper [_____]. That the sequence upon reduced cooling load is: close CCV, close economizer damper, open HCV until the MAT is 53F. Verify the reverse during an increase in cooling load. Observe that when the OSAT is > RAT, the economizer dampers are closed and that the min. OSA damper is always open [_____]. Verify that DAT is maintained within +/- 1.5F of setpoint, without hunting. [____].[_____] and that the DAT is being reset according to the schedule [_____].	
19.	--	Return all changed control parameters and conditions to their pre-test values5	Check off in Section 2 above when completed.	

MONITORING AND TREND LOGGING.

Monitoring via BAS trend logs are required per test Procedures 16, 17; 18. Trend logs all shall be provided in electronic continuous columnar spreadsheet compatible format. Trends all shall be provided in hard tabular format (continuous columnar with time in left column and at least four columns of point values in adjacent columns). All points for a given trend will begin at exactly the same time. Provide a key to all abbreviations. Attach representative graphs or columnar data and explanatory analysis to this test report.

Record Foot Notes

1. Sequences of operation specified in Contract Documents (attached).
2. Step-by-step procedures for manual testing, trend logging or data-logger monitoring.
3. Include tolerances for a passing condition.
4. Record any permanently changed parameter values and submit to OWNER.

REPRESENTATIVE TEST

TEST 3 OF 3. TYPE: C - SIMPLE

Project:_____

FT-____ HEATING FAN COIL FCU-1

Related Tests: Boilers

1. Participants

Party	Participation
_____	_____
_____	

Party filling out this form and witnessing testing _____

Date of test _____

2. Prerequisite Checklist

a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:__ FCU-1

b. __ Boilers 1; 2 have successfully completed functional testing.

c. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints, schedules, debugging, loop tuning and sensor calibrations complete.

_____ _____
Controls Subcontractor Signature or Verbal Date

d. __ All A/E punchlist items for this equipment corrected.

e. __ Safeties and operating ranges reviewed.

f. __ Test requirements and sequences of operation attached.

g. __ Schedules and setpoints attached.

h. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.

i. __ BAS Program Review. Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.

j. __ Packaged Control Program Review. Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.

k. __ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts,
Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values √
FCU-1 setpoint		

Parameter	Pre-Test Values	Returned to Pre-Test Values √

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK1	1st Gage or Pkg & BAS Values	Instru. Meas'd Value	Final Gage or Pkg & BAS Values	Pass Y/N?
FCU-1 stat temp.		Stat:		Stat:	

1Sensor location is appropriate and away from causes of erratic operation.

4. Device Calibration Checks.

---NONE---

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____

__ Unit mounted securely. __ Unit accessible for servicing. __ No unusual noise or vibration in fan.

6. Functional Testing Record

Proced. No. & Spec. Seq. ID1	Req ID No.2	Test Procedure3 (including special conditions)	Expected and Actual Response4 [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1 Seq. 1		Adjust the stat setpoint until it is equal to the space temp.	__Fan starts. __ Heating coil valve opens; __warm air delivered.	
2 Seq. 1		Adjust the stat setpoint until it is 4F below the space temp.	Fan stops. Heating coil valve closes.	
3	--	Return all changed control parameters and conditions to their pre-test values5	Check off in Section 2 above when completed	

Record Foot Notes

1 Sequences of operation specified in Contract Documents (attached).

2 Mode or function ID being tested, per testing requirements section of the project Specifications.

3 Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

4 Include tolerances for a passing condition.

5 Record permanently changed parameter values and submit to Owner.

END OF TEST

END OF SUPPLEMENT 2 to SECTION 019113

SECTION 019113 - GENERAL COMMISSIONING REQUIREMENTS

SUPPLEMENT 4

SAMPLE SEQUENCE OF OPERATION

Chilled Water System

System Description

Areas Served

The chillers serve together all building cooling loads except for two small packaged rooftop units serving Elevator Rooms 121-12 and 13.

Description

The Chiller System is Comprised of Three Chillers: Two larger centrifugals (CH-1 and 2) with good part load efficiency down to 25 percent and one reciprocating chiller (CH-3) about one-third the size of the centrifugals which has excellent part load efficiencies with eight stages of unloading.1 Each chiller has a dedicated constant flow primary pump which feeds into a variable speed secondary pumping system comprised of two lead/lag pumps in parallel with a third backup pump.

There is no automatic chiller staging/selection optimization controls. The preferred sequence of chiller staging may vary by season. There is a secondary chilled water supply loop with variable speed drives on the pumps controlled from differential pressure, which is reset incrementally to operate at the lowest speed and pressure possible to satisfy the current load. There are three cooling towers, each assigned to one chiller. There is also a heat exchanger in the condenser water loop that rejects heat from ACU-1-10 and CRU-1, which requires the lead cooling tower to operate year-round. The building automation system (BAS) controls many of the chiller functions and setpoints and just enables others, and monitors a number of points through the chiller interface. BAS in brackets denotes where the BAS has control over the setting or parameter, rather than the local chiller packaged control panel.

Scheduling

The chiller is enabled year-round and will start upon a cooling call as described below.

Sequences

Note: Sequences 6 and 33 are designed to defer to resetting the chilled water pressure down to its minimum, before the chilled water supply temperature is reset upwards.

1 Including pump energy, at high loads (75 percent to 100 percent of chiller capacity) the centrifugals are more efficient, at 50 percent the centrifugals and reciprocating chillers are about equal and at 25 percent load the reciprocating chiller is more efficient. Since 25 percent load on the small CH-3 is expected to rarely be encountered for any period of time, CH-1 and 2 should primarily be used.

Chillers (CH-1, 2; 3)

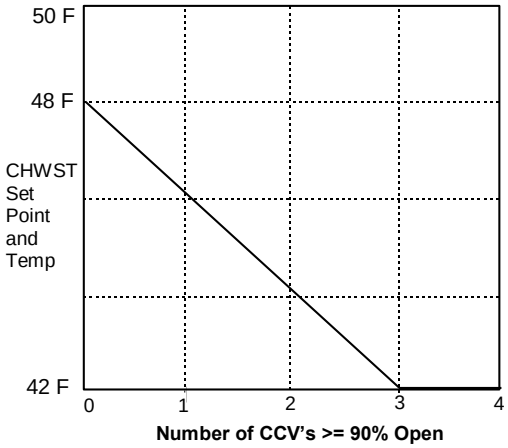
1. Software [BAS] lead lag selector to allow any of the chillers to act as the lead machine.
2. Chiller will only be enabled to operate in AUTO upon the following conditions:
   a) Chiller scheduled ON [by BAS].
   b) OSAT > 56 degrees F [BAS] (shuts back OFF at OSAT < 54 degrees F).
   c) There are no active alarms that initiate a shutdown (reported to BAS and chiller panel).
   d) The cooling tower (CT) sump temperature is above its minimum [BAS and chiller panel].
   e) There is a call for cooling [BAS].
   f) Chilled and condenser water flows are verified [BAS and chiller panel].
3. Upon a call for cooling2, the lead primary CHW pump starts and the pump status is confirmed ON via a current sensor in the BAS and flow is confirmed through a flow switch . Then the assigned lead chiller oil pump starts, then the lead condenser water pump starts and the pump status is confirmed ON via a current sensor in the BAS and flow is confirmed through a flow switch. There are 30 to 60 second delays between these pumps, per the chiller integral programmed settings (adjustable). The lead secondary CHWP then starts, ramping up from the minimum speed of 20 Hz

via the variable frequency drive (VFD). (20 Hz was determined from performing an amps vs. Hz test. 20 Hz is the lowest the motor can go without the amps beginning to increase.)

2 A call for cooling is when a cooling coil valve (CCV) on one of the ON AHUs (AHU 1, 2, 3 or 4) is at least 15 percent open for at least 10 minutes. It is noted that the chiller packaged controls designate a call for cooling to be when the CHWST SPt is xx degrees lower than actual CHWT. This is inactive by being set to 0.

4. The lead chiller then starts with the prerotation vanes closed, which begin to open (closed to full open in ~ 3 minutes and full open to closed in ~1 minute).
5. The chiller maintains the CHW supply temperature at the setpoint [BAS] which ranges from 42 degrees F to 48 degrees F, based on a reset schedule, by modulating chiller capacity. CH-1 and CH-2 utilize prerotation vanes for capacity control, while the reciprocating chiller, CH-3, utilizes eight stages of unloading.
6. Chilled water supply temperature (CHWST) reset [BAS]: The CHWST will have a default of 44 degrees F. The chilled water temperature will be reset upward only when the secondary pumps' speeds are at their minimum (as described in Sequence 33). This is because, lowering pump speed with the differential pressure reset strategy (Sequence 33) competes with CHWST reset, but DP reset will save more energy than resetting the chilled water temperature up, per ton of cooling.

   When the pump speed is at its minimum allowed, the CHWST reset routine is started and continues until one or more pumps are above their minimum speed, then hold the CHWST setpoint where it is until the pumps are at their minimums. Include a differential or time delay to prevent hunting. Likewise, CHWST setpoint will not lower from current conditions until all secondary pumps are at their maximum speed. This deference to the pressure reset is accomplished by starting the pressure reset downward when all CCVs are less than 90 percent open and not starting the CHWST reset upward until all CCVs are less than 80 percent open. When enabled, the CHWST reset sequence is: when all CCVs are less than 80 percent open, the CHWST setpoint (SPt) is at its highest value of a proportional range (48 degrees F). When three or more CCVs are 80 percent or more open, the CHWS SPt is at its lowest value (42 degrees F).



7. The CHWST reset will not increase when the return air relative humidity rises above 50 percent [BAS].
8. Chiller Staging. [All in BAS]: There is no automatic chiller staging/selection optimization controls. The first lag chiller will be called for whenever the secondary CHW flow exceeds the primary CHW flow for 20 minutes (adjustable) as determined by flow meters AND the lead chiller is 95 percent loaded (by percent of rated current).3 For reference, each secondary CHW pump is design rated at 765 gpm. After a call has been maintained for the 20 minutes, the first lag chiller and pump sequence start as described above for the lead chiller. The second lag chiller will start under the same conditions and sequences. Whenever a lag chiller starts, all running chillers load and unload as necessary to be running within 5 percent of the same percent load (based on rated current).

   3 This 95 percent load parameter will allow CH-3 to operate as the lead chiller, if desired, up to its full load before the much larger chillers (CH-1 and 2) start, since there is such a difference in primary CHW flow between CH-1 or 2 and CH-3, but no difference in the secondary CHW pump flows for the different chillers.

9. The last selected lag chiller and associated pumps stage OFF when the total primary CHW flow exceeds the total secondary CHW flow by the capacity (flow) of the last selected chiller's primary CHW pump for a 20 minute duration (adjustable).
10. All chillers and pumps will turn OFF when OSAT is < 55 degrees F for _____ minutes [BAS], OR when all CCVs are less than 15 percent open for 10 minutes [BAS], OR when all air handlers are OFF [BAS], OR when an unoccupied schedule occurs (subject to night low limit conditions not being met) [BAS], OR when failure alarms are registered (BAS and chiller controls).

Misc. Chiller Features

11. Chillers will not cycle ON and OFF more than three times in a 1-hour period (chiller controls).
12. Alarm on Chiller Failure: Failure alarms must be manually reset. See other alarm modes in chiller operator's manual [alarms created by chiller controls, shutdown by chiller controls, message sent to BAS].
13. Demand Limiting: [BAS] Demand limiting setpoint adjustment may be made through building automation system [BAS]. The demand limit (in sum of all chillers kW), when met will delay the start of the next chiller for 1 hour (adjustable). This sequence is different than the disabled stock sequence in the chiller packaged controls.
14. The BAS will monitor kW and calculate the load on the chiller using evaporator CHW flow and temperature differentials [BAS].
15. Provide emergency stop switch located adjacent to chiller room mandoor exit to stop all equipment in chiller room, except ventilation system. Ventilation fan to automatically operate on purge mode with activation of emergency stop switch.

Primary Chilled Water Pumps (CHWP 1, 2, 3 for CH-1 & 2 and CHWP 4; 5 for CH-3)

16. Each primary CHW pump is assigned to one chiller [BAS]. Lead primary CHW pump starts upon a call for cooling per above chiller sequences. Lag primary CHW pump starts upon a call for the lag chiller per above chiller sequences [BAS].
17. Primary CHW pumps to operate continuously when their associated chiller is running. Primary CHW pumps provide constant flow through the chiller according to the manufacturer's recommendations: 675 gpm for CH-1 and CH-2 and 180 gpm for CH-3. Check balancing report for finals.
18. A standby (redundant) primary CHW pump is provided for CH-1 and 2 together and can be operated as active pumps after opening manual valves. A standby primary CHW pump for CH-3 will automatically change over [detected by BAS and chiller controller; pump control by BAS].
19. a) CHWP 1, 2; 3: Alarm on pump failure detected via a motor current switch and flow switch. Upon failure of lead pump, chiller shuts down and lag chiller should start automatically to meet load [BAS].
    b) CHWP 4; 5: Alarm on pump failure detected via a motor current switch and flow switch. Upon failure of lead pump, standby pump automatically starts [detected by BAS and chiller controller; pump control by BAS].

Chiller Condenser Water Pumps (CDP 1, 2, 3, 4; 5)

20. CD pumps CDP 1, 2, 3 for CH-1 and CH-2 and CDP 4, and 5 for CH-3 to operate continuously when their associated chiller is running. CD pumps provide constant flow through the chiller condenser according to the manufacturer's recommendations: 1,350 gpm for CH-1 and CH-2 and 360 gpm for CH-3.
21. A standby (redundant) CD pump is provided for CH-1 and 2 together. The pump can be operated as an active pump after opening and closing appropriate manual valves. A standby pump is provided for CH-3 and will automatically changeover [BAS].
22. a) CDP 1, 2; 3 (CH-1; 2): Alarm on pump failure detected via a motor current switch and flow switch. Upon failure of lead pump, chiller shuts down and lag chiller should start automatically to meet load [detected by BAS and chiller controller; pump control by BAS].
    b) CDP 4; 5 (CH-3): Alarm on pump failure detected via a motor current switch and flow switch. Upon failure of lead pump, standby pump automatically starts [detected by BAS and chiller controller; pump control by BAS].

Cooling Tower (CT-1, 2; 3)

21. Cooling towers operate with operation of their associated condenser water pump or with the operation of the ACU condenser pump (see Sequence 41). With operation of a pump, open selected tower supply (isolation) valve and allow tower temperature control to function [BAS].
22. Software selector to allow any tower to be the lead tower, second tower or third tower [BAS].
23. a. CT Sequences. [All BAS] The CT during the normal cooling season rejects heat from the chillers and returns as cool of water as can be efficiently achieved to the chiller's condenser. A reset schedule is used: ECDWT setpoint equals the outside air wet bulb temperature plus 7 degrees F, but not lower than 65 degrees F, nor higher than 83 degrees F.

    The CT will try and maintain the ECDWT setpoint temperature by first modulating the normally open bypass valve, with no water going over the top of the tower. When the valve is in full bypass AND the ECDWT is greater than the ECDWT setpoint, the bypass valve begins to close and the normally closed CT control valve associated with the respective CT and CDW pump, opens 100 percent and water goes over the respective CT. (See (b.) for additional details). The bypass valve continues to modulate open to try and maintain the ECDWT setpoint without the CT fans.

    When the bypass valve is fully closed and the ECDWT reaches 2 degrees F above the setpoint, the setpoint is

achieved by successive cooling tower stages. There are six CT stages:

CT Stage	CT1 Low Fan	CT2 Low Fan	CT3 Low Fan	CT1 High Fan	CT2 High Fan	CT3 High Fan
0						
1	X					
2	X	X				
3	X	X	X			
4			X	X		
5				X	X	
6				X	X	X

Every 4 minutes the ECDWT is polled. When the ECDWT reaches 2 degrees°F above the setpoint, the tower stage is increased by one. If the ECDWT is more than 1 degrees F below setpoint, the CT stage is lowered by one.

b. If only CH-3 is ON, only the CT cell fan currently ON will run. (One CT is always ON to serve HE-1). Upon CH-3 AND CH-1 or CH-2 being ON together, then another CT cell will come ON. With only CH-1 OR CH-2 ON, two CT cells will be ON. The intent of these sequences is to not waste CT fan energy when not very much water is flowing over the tower.
c. The lead CT isolation valve modulates with the bypass valve inversely proportional. This is required to 1) provide warmer water, faster to CH at startup, 2) to prevent excess water from overflowing the CT basin, and 3) even with the small heat exchanger (HE-1) running, some water still goes over the top of the tower resulting in freeze potential. This strategy will prevent water from going over the tower during these conditions.

24. When a lag chiller comes on line, its condenser water pump and associated CT come on line [BAS].
25. A multiple position CT sump or basin level sensor provides the following information to the BAS:
    a) High water alarm; low water alarm.
    b) Open make up water valve; closed make up water valve.
    c) System shutdown.
    d) Alarm on heater stage failure detected via current sensing switch.
26. Cooling tower sump two stage heaters shall be controlled to maintain a sump temperature of 45 degrees F with the following schedule [BAS]:

	ON (°F)	OFF (°F)
Stage 1	48	50
Stage 2	45	48

    CT1 and CT2 have a sump temperature sensor. Each CT area in the sump has a two-stage heater. All heaters of all CTs of a given stage act together on indication by any of the two sensors of low temp.
27. Cooling tower makeup valve (one for all three CTs) to maintain sump water level. Upon sensing a drop in water level, slowly open makeup valve in industrial cold water line [level sensor by BAS].
28. Alarm on pony and main motor upon motor failure detected via current sensing relay. Upon failure of fan motor, lag CT starts automatically [BAS].
29. Alarm on excessive vibration detected via vibration limit switch. Upon failure of fan, lag CT starts automatically [BAS].
30. The lead cooling tower operate during periods, when the chillers are OFF (even during winter) to maintain a heat rejection source for the heat exchanger HE-1, which serves approximately 40 tons of cooling from ACU-1 through 10 and CRU-1. See sequences for CDP 6, 7, 8; 9.

Secondary Chilled Water Pumps (CHWP 6, 7; 8)

31. Software lead/lag function allows any of the secondary pumps to act as the lead pump [BAS].
32. Lead secondary CHW pump starts upon a call for cooling per above chiller sequences. Lag secondary CHW pump starts upon a call for the lag chiller per above chiller sequences [BAS].
33. Differential Pressure Control [All BAS]: The objective is to always have one CCV 90 percent open so the pumps operate at the lowest speed and pressure possible to satisfy the current load. Every 5 minutes the CCVs are polled. A PI loop that changes the secondary pump discharge differential pressure setpoint to maintain the remote (local on 8th floor) DP setpoint to maintain the most open CCV at 90 percent open (with a deadband of +/-_____). For example: When the most open CCV is more than 90 percent open, a PI signal is calculated and changes the local DP setpoint upward. When the local DP setpoint is not being met, a PI signal is calculated and sent to the pump discharge pressure setpoint and it is raised accordingly. Through another PI loop, the variable speed (frequency) drive (VFD) increases the pump motor speed to meet the raised pump differential (discharge) pressure setpoint.

The remote DP setpoint will be maintained between maximum and minimum pressures. The maximum pressure limit is the pressure required to provide full flow to all CCVs simultaneously (per TAB). The minimum pressure limit is the pressure correlating to the lowest speed the pump motor is allowed to be operated at (per motor manuf. and TAB).
Maximum pressure limit:_____psi. Minimum pressure limit:_____psi.
The VFD internal settings will allow the VFD to run the pumps to their minimums.
Number of remote DP sensors: _____. Locations: _____
_____

**Differential Control and CHWST Reset. The DP reset and CHWST reset compete with each other for control of the building. Sequence 6; 33 have the net effect of deferring to the pressure reset over the CHWST reset. The CHWST reset won't come into play until all the CCVs are less than 80 percent open, which won't occur until the pressure reset is at its minimum.

34. Pump Staging [BAS]: With one secondary CHW pump running, when the total secondary CHW gpm exceeds the lead secondary CHW pump design gpm for 10 minutes (all adjustable), start the first lag pump. Both pumps converge and run at similar speeds and gpm to maintain the common discharge pressure differential setpoint and the remote DP setpoints. If the total secondary gpm exceeds the total design gpm of the running pumps (lead and first lag) for 10 minutes, start the second lag pump. All three pumps converge and run at similar speeds and gpm to maintain the common discharge pressure differential setpoint and the remote DP setpoints.
35. During reducing load as the DP increases: when the total secondary CHW gpm has reduced to be equal to or less than the sum of the first two selected pumps' gpm for 10 minutes (adjustable), the second lag secondary CHW pump shuts OFF. Similarly, when the total secondary CHW gpm, with two pumps ON, has reduced to be equal to or less than the gpm of the lead CHW pump for 10 minutes, the first lag pump shuts OFF.
36. The controller shall monitor rpm and gpm of the pumps and shall not allow operation of the pumps at or beyond their published "End of Curve" [BAS]. Upon sensing an end of curve condition, via a pump curve equation, the next pump will be staged ON.
37. Alarm on pump failure detected via current sensing switch. Upon failure of pump, next lag pump starts automatically (BAS and chiller controller).
38. Alarm on failure of VFD [BAS].
39. The rpm of secondary CHW pumps to be monitored by BAS.
40. For coil freeze protection during smoke exhaust system operation, pumps CHWP-6, 7; 8 to run under NORMAL control and all cooling coil valves to open with operation of respective AHU when smoke exhaust system (EF-10) is in operation AND outside air temperature is below 40 degrees F [BAS].

ACU Condenser Water Pumps (CDP 6, 7 and 8; 9) and HE-1

41. The lead cooling tower operates during periods, when the chillers are OFF (even during winter) to maintain a heat rejection source for the heat exchanger HE-1, which serves approximately 40 tons of cooling from ACU-1 through 10 and CRU-1. CDP 6 or 7 (one is redundant) provides water from the heat exchanger to the cooling towers. CDP 8 or 9 (one is redundant) services the ACUs and CRU-1 from HE-1. The selected CD pump for each loop (CDP 6 or 7 AND 8 or 9) operate continuously [BAS].
42. During chiller OFF periods, the ECDWT setpoint and CT bypass valve and fan staging parameters remain the same as during chiller ON periods (see above).
43. Alarm on pump failure detected via current sensing switch. Upon failure of any pump, standby pump automatically starts [BAS].

General Chiller Operation During Unoccupied Periods

44. Unoccupied Operation: During scheduled unoccupied hours at night or weekends, the chiller system is in standby, except the cooling tower operates as required to maintain 65 degrees F condenser water to the heat exchanger HE-1 for heat rejection of ACU-1 through 10 and CRU-1.

Winter Operation.

45. During winter, the chiller system is in standby, except the cooling tower operates as required to maintain 65 degrees F condenser water to the heat exchanger HE-1 for heat rejection of ACU-1 through 10 and CRU-1.

END OF SUPPLEMENT 4 to SECTION 09113